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This manual is a guide for water quality planners in the evaluation and selectio of agricultural nonpoint source controls for areas ranging in size from individual farms and subwatersheds to large regions. Such controls are specified in water quality plans developed in response to Section 208 of the 1972 Federal Water Pollution Control Act Amendments.

Control practices are described for both irrigated and nonirrigated cropland. The physical and chemical nature of nonpoint source pollutants and the pathways by which these pollutants are transported from field to water body are examined. Pollutants discussed include nutrients, sediment, animal wastes, salts and pesticides. Controls involve tillage methods, cropping practices, and methods of pesticide and fertilizer application.

The evaluation methodology involves seven steps: description of the watershed, identification of the problem, determination of applicable control measures, choice of the unit of analysis, establishment of the base condition, evaluation of control measures, and development of an optimal control strategy. Two case studies demonstrat the application of the evaluation methodology to watersheds in Ohio and Washington.

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PLANNING GUIDE FOR EVALUATING AGRICULTURAL NONPOINT SOURCE WATER QUALITY CONTROLS

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management and engineering tools to help pollution control officials achieve water quality goals through watershed management.

Pollutants in runoff and seepage from urban, agricultural, and forested areas contribute significantly to water pollution problems in many areas of the United States. Control strategies for reducing nonpoint source pollution require a body of knowledge and set of analysis methods that reflect the complex nature of the problem. This manual was developed as a guide for water quality planners who must design cost-effective nonpoint source controls for irrigated and nonirrigated cropland as part of areawide water quality management strategies.

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ABSTRACT

This manual is designed to serve as a guide for the evaluation and selection of agricultural nonpoint source controls. Such controls are specified in water quality management plans developed in response to Section 208 of the 1972 Federal Water Pollution Control Act Amendments. Control practices are described for both irrigated and nonirrigated cropland. The evaluation methodology presented is applicable to areas ranging in size from individual farms and sub-watersheds to large regions.

The manual contains five sections including the introduction, and six appendices. Section 2 presents the physical and chemical nature of nonpoint source pollutants and the pathways by which these pollutants are transported from field to water body. Pollutants discussed include nutrients, sediment, animal wastes, salts, and pesticides.

Controls involving tillage methods, cropping practices, and methods of fertilizer and pesticide application are described in Section 3. Control options are categorized according to the relative permanence of the measures into three groups: structural, vegetative, and managerial.

Section 4 presents the actual evaluation methodology, which involves the following seven steps: 1) Description of the watershed, 2) Identification of the problem, 3) Determination of applicable control measures, 4) Choice of the unit of analysis, 5) Establishment of the base condition, 6) Evaluation of control measures, and 7) Development of an optimal control strategy. Problem identification, Step 2, is actually beyond the scope of the manual and is assumed to have been completed in earlier planning stages. The end-product of these steps is a ranking of the cost-effectiveness of specific practices controlling pollutant pathways in a region.

Two case studies described in Section 5 demonstrate the application of the evaluation methodology to watersheds in Ohio and Washington States. A single farm is evaluated as part of the Washington State case study.

The planning manual is supported by the following six appendices which provide details of pollutant transport processes and methods of evaluation:

A. Estimating Nonpoint Source Sediment and Nutrient Loadings from Non-Irrigated Croplands
B. Sediment and Nutrient Loss Estimates from Irrigated Agriculture
C. Estimating the Effectiveness and Costs of Salinity Control Measures

D. Nonpoint Source Water Quality Problems Related to Animal Agriculture
E. Water Quality Impact and Control Alternatives Associated with the Use of Insecticides
F. Economic Perspective and Evaluation Methods for Agricultural Nonpoint Source Water Quality Management

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SECTION I

INTRODUCTION

Excessive growth of aquatic plants in Lake Erie decreases game fish populations, increases the level of treatment necessary for municipal drinking water supplies, and discourages recreational use of the water. High salt concentrations in the Colorado River make the water unfit for irrigation purposes, drinking water, and other municipal/industrial uses. These are both nationally publicized cases of serious, long-term water pollution problems. The major source of pollution in these cases is not industrial and municipal discharges, considered to be the cause of most serious water pollution problems in the country. The source rather is runoff and seepage from urban, agricultural, and forested areas. Pollution such as this, which originates from an unconfined source not from a localized source such as a pipe, is referred to as nonpoint source (NPS) pollution.

In 1972, the Federal Water Pollution Control Act Amendments (FWPCA) were passed in response to a recognition of the seriousness of both point and nonpoint water pollution problems. The national objective for water quality improvement as set forth in section 101(a) of the 1972 Amendments, is "to restore and maintain the chemical, physical and biological integrity of the nation's waters." The act states that by 1985, pollutant discharges into navigable waters from point and nonpoint sources shall be eliminated. An interim goal of this act is to provide for the protection and propagation of fish, shellfish, and wildlife, and to permit recreation in and on the water, wherever feasible, by July 1, 1983.

Section 208 of the FWPCA amendments calls for areawide water quality management plans to be developed and implemented by each state to insure adequate control of both point source and nonpoint source pollution. These plans must identify water quality problems and possible sources of associated pollutants, and propose methods for pollution control. Although the development and implementation of these plans is the primary responsibility of each state, financial and technical assistance is available from the federal government.

PURPOSE OF MANUAL

The purpose of this manual is to serve as a guide for the development of agricultural nonpoint source controls called for in 208 water quality management plans. Step by step procedures outlined in the manual provide a basis for the cost-effectiveness ranking of specific practices controlling pollutant pathways in watersheds. Criteria and computational methods for evaluating different control strategies are presented. The manual is designed to be used in preliminary planning stages, not in the final stages of site-specific design.

SCOPE OF MANUAL

The material presented in this manual is oriented towards water quality planners involved with nonpoint source pollution control programs. It is assumed that the planners are familiar with the problem and the geographic area to be evaluated. Knowledge of typical farm enterprises in the region and the engineering feasibility of control practices is assumed. The planning team may have to consult with various federal, state, or local groups to gain this familiarity. The Soil Conservation Service (SCS/USDA) and State University Departments of Agronomy, Agricultural Engineering, and Agricultural Economics can provide valuable assistance.

The methodology presented in this manual is appropriate for the design of nonpoint source controls for all irrigated and nonirrigated cropland. It can be used to evaluate areas ranging in size from individual farm fields to large regions. With such broad applicability, specific soil, crop, precipitation and other physical as well as economic data are not supplied. The case studies presented in Section 5 demonstrate how the methodology is applied in specific situations. The accompanying technical reports provide details of computational methods and data collection procedures.

This manual focuses on three key pollutant categories: crop nutrients, sediment, and salts. Methods of estimating losses of these pollutants are presented. Livestock waste and pesticides are covered as separate pollutant categories. Evaluation methods for estimating losses of these pollutants are less well developed, thus these pollutants are treated in less detail.

USE OF MANUAL

Because nonpoint source pollution is both a relatively recent concern and a complex phenomenon, many unknowns remain. The extent to which agricultural sources contribute to the total pollutant load, the extent to which various control practices decrease this load, and the effects of reduced pollutant loads on water quality are generally not easily determined. The manual makes certain assumptions concerning how this information is to be derived. The manual assumes that:

1) Water quality problems have been defined and associated pollutants have been identified in previous stages of planning,
2) The relative contribution of agricultural sources to the total pollutant load has been estimated,
3) The pollutant load delivered to the waterbody will be reduced by reducing edge-of-field losses,
4) Physical and economic mathematical models used to estimate cost-effectiveness of practices are sufficiently accurate to use for the purpose of comparing the relative cost-effectiveness of different control strategies, and
5) Some field data collection may be required. The manual lists data required for the various steps of the evaluation, and indicates where field studies may be necessary.

SECTION 2

THE PROBLEM

AGRICULTURAL PRACTICES AND THEIR IMPACT ON WATER QUALITY

Guidelines for Water Quality Improvement

The Environmental Protection Agency (EPA) Guidelines for State and Areawide Water Quality Management Program Development (EPA, 1976) suggest that "Best Management Practices" be identified and implemented for categories of pollutants. A Best Management Practice (BMP) is defined as "a practice or combination of practices that is determined by a state (or designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable means (including technological, economic, and institutional considerations) of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals". EPA advises that wherever possible, **practices should concentrate on controlling each pollutant at its source.** Since collection and treatment of polluted water is generally complex and expensive, treatment is to be resorted to only in situations where preventive measures will not result in the attainment of desired water quality standards.

Cost sharing for the implementation of BMPs was authorized by the Rural Clean Water Act of 1977. BMPs to control nonpoint source pollutants are installed and maintained under 5-10 year contracts with cooperating land owners.

Point and Nonpoint Sources of Pollution

Whereas point source pollutants have a localized identifiable source, typically a pipe, nonpoint source pollutants originate from an unconfined source, typically a relatively large area of land. Sources include land used for agriculture, silviculture, mining, and construction. Urban land over which stormwater flows is another source. Transport of pollutants from nonpoint sources to water bodies is by overland flow, percolation, and erosion and sedimentation. Pollutants which may originate from agricultural land include nitrogen, phosphorus, sediment, manurial organic matter, salts, and pesticides.

The unique characteristics of nonpoint source pollution pose special problems which require a body of knowledge and set of methods very different from point source pollution problems. Whereas identifying the origin and measuring the discharge associated with a point source involves well-established techniques which are accurate and easily applied, identifying and assessing the magnitude of nonpoint source contributions requires new and very different techniques.

The complexity of control strategies required for nonpoint source pollution reflects the complex nature of the problem. Nonpoint pollutants are not transported or delivered to water bodies in a confined manner, therefore there is no efficient and economical means of monitoring. The use of effluent limitations is thus generally not applicable for nonpoint source control. Control strategies, on the other hand, must be developed from a consideration of the many variables controlling pollutant transport. An understanding of the dynamics of chemical cycling in soil and water is required to effectively identify nonpoint sources, assess impacts, and develop appropriate control strategies.

Natural (Base) Loads

Many pollutants, including nitrogen, phosphorus, organic matter, pathogens, salts, and sediment are present to varying degrees in all aquatic systems. It is important to estimate the magnitude of natural pollutant loads before implementing control measures. **Where the base load is relatively large, the improved management of adjacent agricultural lands may not significantly improve water quality.**

Water Use Impairment

Although nitrogen, phosphorus, organic matter, salts and sediment are natural components of all aquatic systems, in excess they can offset critical environmental balances. Table 1 summarizes how nutrients, sediment, animal wastes, salts and pesticides can affect the quality of receiving waters.

Nutrients--

Nutrients, such as nitrogen and phosphorus, are generally present at relatively low concentrations in the aquatic environment (i.e., below 0.3 and 0.05 ppm for nitrogen and phosphorous, respectively). **When man augments the quantities of nutrients in a stream or lake, aquatic productivity can be increased dramatically.** This process, referred to as cultural eutrophication, may reduce the value of the water to humans. Decaying organic matter may produce unpleasant odors and deplete the oxygen supply for aquatic animals. Excess plant growth may interfere with recreational activities such as swimming and boating. Decreased oxygen levels, especially in the cold bottom waters where decaying organic matter tends to accumulate, reduces the quality of game fish habitats. The lake or stream waters can become turbid and noticeably colored. When used as a water supply by municipalities and industries, the level of pre-treatment often must be increased.

Cultural eutrophication is not the only water quality problem caused by nutrient enrichment. Dissolved ammonia at concentrations of more than 0.02 ppm of NH_3 may be toxic to fish. Nitrates in drinking water are potentially

TABLE 1. WATER USE IMPAIRMENT CAUSED BY VARIOUS POLLUTANTS

Pollutant Category	Forms of Pollutant	Primary Impact	Secondary Impact	Tertiary Impact	Notes
NUTRIENTS Nitrogen Phosphorus	• Total - N • Nitrate - N • Ammonia - N • Total - P • Soluble - P	• Lake enrichment causes aquatic plant growth which interferes with recreational uses	• Decreased oxygen levels • Changes color • High nitrate and ammonia concentrations	• High Ammonia conc. (>.02 ppm) can kill fish • Change in BOD encourages non-game fish population • Odor • Increased treatment for water supply • High nitrate conc. (>45 ppm) can be fatal to young children	• Threshold N and P concentrations of .30 ppm and .05 ppm have been associated with accelerated growth of aquatic plants
SEDIMENT	• Suspended Solids	• Fills drainage ditches, culverts, stream channels and reservoirs • Plugs water intakes and filters • Increases wear of power turbines, sprinklers and pumps • Increases water treatment costs • Clog gills of adult fish • Reduces recreational use of water	• Reduces sunlight diffusion • Changes color	• Cover fish spawning areas • Adsorption/desorption of substances from and into solution	
ANIMAL WASTE Nitrogen Phosphorus		SAME AS NUTRIENTS ABOVE			
Oxygen Demanding Materials Pathogens	• BOD • COD • NOD • Fecal coliforms • Fecal streptococci	• Decreased fish populations and recreational uses because of low oxygen levels and fecal contamination • Increased treatment for water supply	• Odor • Taste • Color	• Can result in anaerobic transformation with production of methane, amines and sulfides	
SALINITY Salt Compounds		• Can harm fresh water aquatic fish and plants • Corrosion of pumps and pipes • Greatly increased cost for treatment of water supply		• Delays or prevents crop germination for downstream irrigators • Reduces plant growth and yield	
PESTICIDES Herbicides Insecticides Fungicides Miticides	• Organochlorine insecticides • Carbamate insecticides • Organic phosphorus insecticides • Triazine herbicides • Phenoxy herbicides	• Toxic to fish and aquatic plants	• Sublethal effects • Synergistic effects	• Biomagnifications in food chains • Long term mutagenic effects on cell growth and development	

toxic to humans, especially young infants, since their digestive systems are less acid than those of adults and contain bacteria capable of reducing nitrate-nitrogen to nitrite-nitrogen. Nitrite accumulation in the digestive tract can, in turn, cause brain damage or even death, by reducing the oxygen-carrying capacity of the blood (methemoglobinemia). Consequently, the Environmental Protection Agency (EPA) has set a limit of 45 ppm nitrate for drinking water. Ruminants can also be affected by nitrates via the same chemical processes. Tolerance levels for ruminants have been set somewhat higher than for humans.

Sediment--

Sediment affects the use of water in a variety of ways. **Total suspended solids can reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, and clog the gills of adult fish.** This reduces fish, shellfish and plant populations and decreases the overall productivity of a lake or stream. Recreation is limited because of the decrease in fish and shellfish populations and because of the water's unappealing, turbid appearance.

Sediment also fills road drainage ditches, culverts, and stream channels and shortens the economic life of reservoirs and farm ponds. It can plug water filters, erode power turbines and sprinkler nozzles, and damage pumping equipment. Maintenance costs are increased and additional treatment may be necessary before the water can be used for drinking or industrial purposes.

Much of the sediment transported to waterways originates from agricultural land. Valuable topsoil is thus removed and an increased application of nutrients is required to maintain soil productivity.

Chemicals such as pesticides, solid phase phosphorus, ammonium and organic nitrogen are also transported with sediment in an adsorbed state. Changes in the aquatic environment can cause the release of these chemicals from sediment. Thus, although **adsorbed phosphorus transported by the sediment may not be immediately available for plant growth it may serve as a long-term and continual contributor to lake eutrophication.**

The reverse may also occur; chemicals already present in the water can be scavenged by suspended solids. A pesticide adsorbed to sediment will not necessarily become less toxic, but much of it will settle out of solution at least temporarily.

Animal Wastes--

Animal wastes can contribute nutrients, oxygen-demanding materials, and pathogens to receiving streams. The composition of most manures is such that if enough is applied to meet the nitrogen needs of a crop, phosphorus will be applied in excess of crop needs. Surface runoff from fields to which manure has been applied thus may carry substantial quantities of phosphorus. Leaching of soluble or organic forms of phosphorus from manure application sites is generally negligible because of the soil's capacity to adsorb phosphorus.

The oxygen demand exerted by carbonaceous materials individually or in combination with nitrogen can deplete dissolved oxygen supplies in water, and may result in anaerobic conditions. When the decomposition process becomes anaerobic, methane, amines and sulfide are produced in addition to the carbon dioxide, sulfate, ammonia and nitrates that result from aerobic decomposition. The water acquires an unpleasant odor, taste and appearance and becomes unfit for drinking and recreational purposes. Treatment is often required for industrial use.

Salinity--

Water used for irrigation accumulates salts. **In some areas of the country, water and land quality has been seriously degraded due to salinity.** The total salt burden of western streams may be as much as 40 percent man-caused (Law and Bernard, 1970).

Excess soil salinity can delay or prevent crop germination and substantially reduce the rate of plant growth. High osmotic pressures that develop between the soil solution and the plant root impair the plant's ability to absorb water. Other possible adverse effects of salinity include nutritional imbalances, toxicities caused by specific ions such as boron which can be toxic in small quantities, and poor soil aeration and water transmission if excess sodium accumulates and disperses the soil. The addition of saline irrigation water to surface water bodies limits potential downstream usage for drinking, irrigation or industrial purposes. High salt concentrations in streams and lakes can harm fresh-water aquatic plants just as excess soil salinity damages crops, although salt levels rarely reach such levels except in land-locked bodies such as the Salton Sea (50,000 mg/l) or the Great Salt Lake (270,000 mg/l).

Pesticides--

Pesticides include insecticides, herbicides, mitacides, nematocides, rodenticides, fungicides, plant growth regulators, and desiccants, all of which are used extensively in agriculture and silviculture. The utilization of pesticides in agriculture has greatly increased since they were first used in the 1940s. According to USDA, in 1976, 1015 million pounds of pesticides were used in this country. Of this quantity, about 65% were used on farms (von Rumker, et al., 1975). Approximately 56% of all nonpasture cropland was treated with herbicides and 18% was treated with insecticides.

Although the benefits of pesticide use are substantial, there are also environmental risks related to its use. **Some types of pesticides or their metabolites are resistent to degradation.** Degradation products may persist and accumulate in aquatic ecosystems. The entire food web including man can be affected.

Sublethal effects include those behavioral and structural changes in an organism which jeopardize its survival. For example, certain pesticides have been found to inhibit bone development in young fish or affect reproduction by inducing abortion.

Herbicides typically degrade quickly, however can destroy non-target vegetation in the aquatic environment that serves as a food source for higher organisms. Indirect effects of herbicide use thus include the disruption of food chains and the addition of organic material to waters promoting eutrophication.

Biomagnification is a phenomenon which occurs if a pesticide is taken in by an organism but not excreted. An organism will accumulate a higher pesticide concentration than is present in the organisms upon which it feeds.

Physical Factors Affecting the Degree of Water Quality Impact

Stages of Pollutant Transport--

The process by which a substance is delivered to a stream can be described in terms of three stages: availability at the field site, detachment, and transport (Figure 1). Only when a pollutant is available in some form at a site, becomes detached, and is transported to a receiving body does it constitute a potential pollution hazard.

Factors which determine the nature of the pollutant delivery process in a given situation include precipitation, temperature, topography, soil type (including antecedent moisture conditions), **cropping practices and irrigation applications.** Physical characteristics of the receiving water body affect the actual impact of the pollutant after it is delivered.

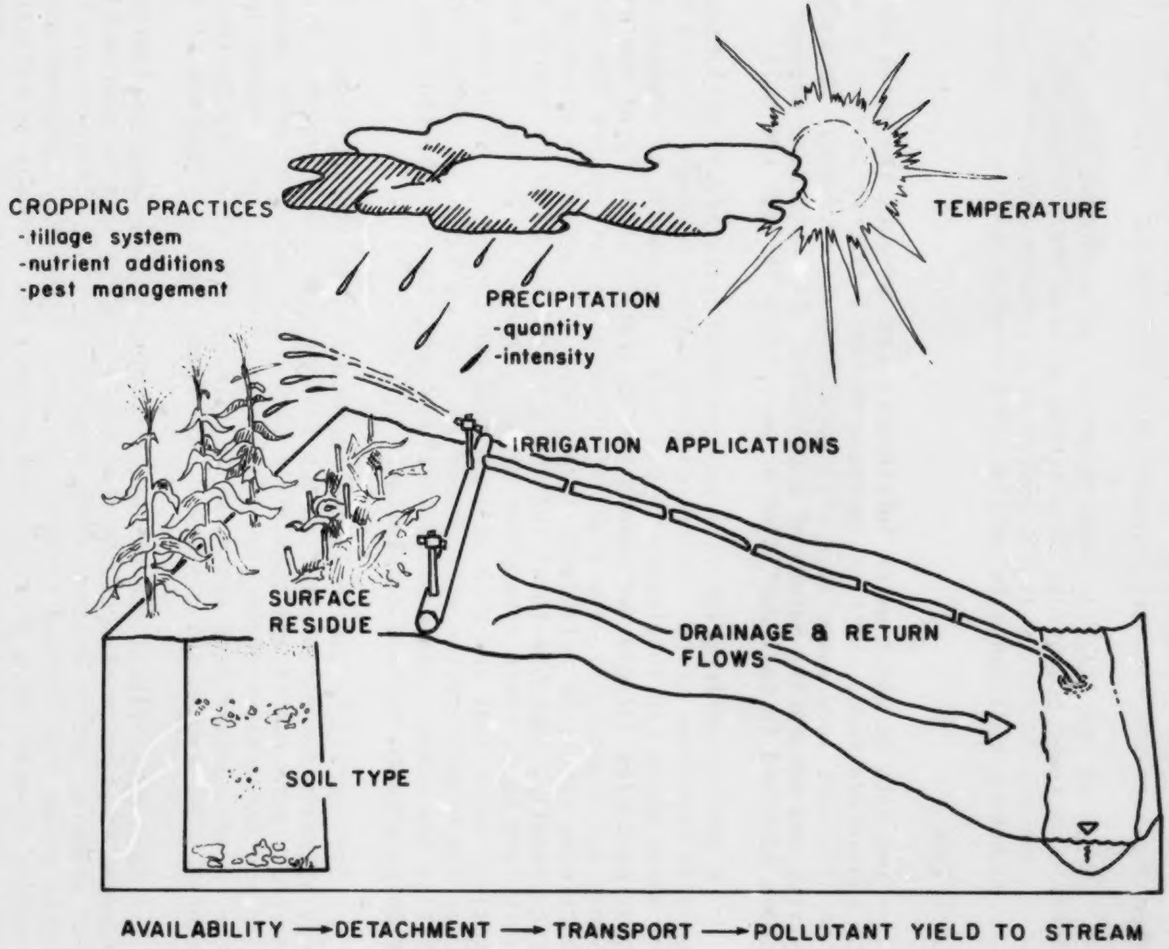
Precipitation and Temperature--

Temperature, rainfall pattern, and snow melt are important climatic variables that affect infiltration, surface runoff, and soil erosion. At lower temperatures, the rate of nutrient uptake by plants decreases. More nutrients in the soil may thus be available for detachment and transport, however less nutrients will be taken up by plants in the receiving water bodies. The effects of any increase in nutrient transport are further offset during cold weather by the capacity of cold water to hold more oxygen than warm water.

High intensity storms generally increase the runoff of water and the dislodgement and transport of pollutants. Over shorter periods of time (for the same total rainfall) the water will have less opportunity for infiltration. The high kinetic energy of raindrops causes larger soil particles to be dislodged from the surface and transported with runoff waters and smaller particles to become cemented, sealing the soil surface. Raindrop impact of high intensity storms also tends to seal the soil surface.

Melting snow can contribute significantly to the runoff-erosion process. An increase in runoff, which often results from rapid snow melt, provides greater energy to dislodge and transport soil and associated adsorbed substances and increases the volume of water for transporting soluble materials.

Figure 1. Stages of pollutant movement from cropland to streams.



Topography--

The capacity of water to dislodge and transport material increases with its velocity. As water moves downslope its velocity increases. The steeper the slope, the faster the increase, and the longer the slope, the greater the water volume and velocity at the bottom. With higher velocities, erosion and overland flow are promoted and infiltration inhibited.

Shape of the slope is also important, with concave hills generally delivering fewer pollutants to a stream or lake than convex hills. Transport capacity decreases at the bottom of a concave slope, allowing some of the suspended pollutants to settle. The reverse is true of convex hills.

Soil Type--

The rate at which water infiltrates soil affects the ratio of surface to subsurface flow. With an increase in the infiltration rate of a soil, the pollutant load associated with runoff should decrease. **Both the solubility and adsorptive nature of a pollutant will determine whether it becomes adsorbed to soil particles or percolates through the soil.**

A soil's infiltration rate and its ability to adsorb pollutants depends on soil characteristics. Prior moisture content markedly affects the amount of water which can infiltrate into a soil. **The amount of organic matter and clay particles largely determines the adsorption capacity of the soil.** Sandy soils generally have high infiltration rates, because the large soil particles result in relatively large pores, through which water can percolate readily. Because total surface area and the negative charge of these soils are less, their adsorption capacity is generally much less than clay soils. Soils that are both well drained and contain a sufficient amount of clay and organic matter will absorb the most pollutants. Subsoil characteristics may either retard or enhance drainage, thus influencing the partitioning between surface and subsurface flow.

Soil fertility can influence pollutant flux. An increase in fertility may increase evapotranspiration due to increased plant growth. This will decrease both runoff and subsurface flow. The increased crop canopy will provide for greater protection of the soil surface from raindrop impact, and the larger, deeper root system will increase soil stability during runoff events. The eroded soil, however, will have a greater content of nutrients.

Soil type affects the polluting potential of an area by limiting the fundamental choice of cropping practice and/or irrigation system options. For example, poorly drained soils require certain cultivation practices and often allow only limited cropping choices. Excessively drained soils require shorter, more frequent irrigations, and frequent fertilization, and often cannot be efficiently irrigated with conventional surface irrigation methods.

Cropping Practice--

Crop cover protects the land from rainfall impact, thereby decreasing soil erosion and increasing infiltration. In general, the potential for soil erosion and runoff will be smaller the denser the crop cover, the longer the crop is on the land, and the greater the quantity of residue left after harvesting.

Root growth increases soil stability. In addition, crops with deep roots generally require less frequent irrigations. Both enhanced soil stability and reductions in irrigation frequency help to minimize pollutant losses from croplands.

Certain cropping practices can reduce the need for pesticide applications. For example, using more resistant crop varieties may allow reduced pesticide application rates, and mechanical weed control techniques may decrease the need for herbicide use.

Irrigation Applications--

In arid regions, which dominate much of the western United States, agricultural land is commonly irrigated. Irrigation not only increases productivity (by 2- to 3-fold), but also provides flexibility by allowing a farmer to grow a variety of valuable crops such as corn, cotton or sugar beets. However, as **irrigation water moves across and through the furrow-irrigated fields, salt concentrations are increased through evapotranspiration, and other pollutants are leached from the soil.**

The degree of impact that leachate and return flows have on the quality of receiving water is determined to a large extent by the method of irrigation. Irrigation volume and efficiency will vary markedly among furrow, basin, border, sprinkler and trickle irrigation methods. Given a specific method, different system design and operating practices result in widely different efficiencies. For furrow-irrigated fields, for example, the magnitude of runoff and percolation depends on stream size (quantity of water delivered per unit time to the head of each irrigation furrow), furrow slope (steepness of the irrigation channel) and length, frequency of irrigation, set time (length of time each furrow is irrigated during a given irrigation), uniformity of water application, and intake rate (Figure 2).

An increase in either stream size or furrow slope generally increases the detachment and transport capacity of the irrigation flow. Flow decreases as the furrow is traversed, however, so midfield deposition of sediment eroded from the head of the field is common. Usually irrigators reduce stream size as the slope is increased, but the reduction is rarely enough to compensate completely for the slope increase. Set time is often determined by tradition or convenience to the operator, though longer set times coupled with less frequent irrigations generally lead to decreased losses of sediment and adsorbed pollutants. Increased set times, however, may increase percolation.

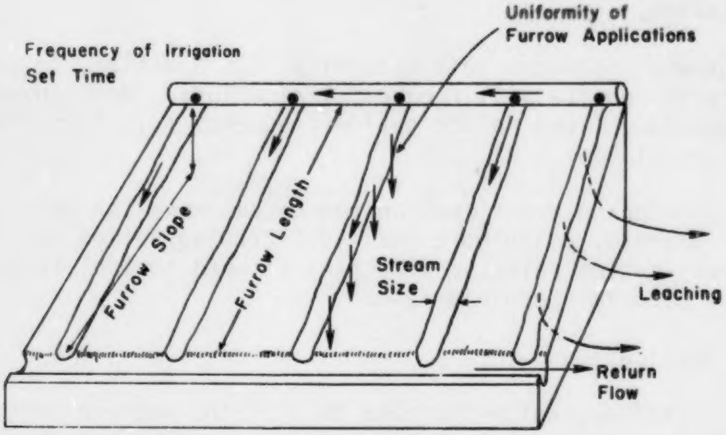


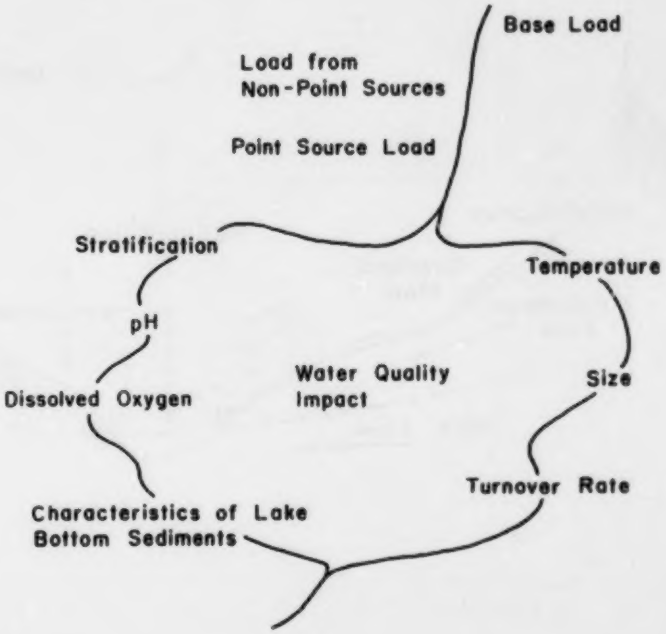
Figure 2. Variables influencing pollutant losses from irrigated fields.

Furrow irrigation is characterized by considerably less uniformity of water application than sprinkler irrigation. Because there is a nonuniform depth of application, the soil below the furrows receives more water than do other areas of the field. Long furrows (larger lengths of run) further decrease uniformity, because the portion of the field near the lower end of the furrow receives a smaller stream flow for less time than do those areas near the upper end of the field. Consequently, less water infiltrates the lower portion of the field. Nonuniformity is disadvantageous because it results in over-application to some portions of the field and/or under-application to other portions. Over-irrigation causes excessive percolation, whereas under-irrigation causes plant stress and decreased crop yields.

Stream/Lake Characteristics--

The quantity of pollutants that may be adequately assimilated by a water body is determined by many factors which cannot be easily controlled. Physical characteristics of the receiving waters, such as size, rate of flow (turnover rate), base load, temperature, and pH all affect the degree to which a substance actually impairs water quality (Figure 3). The larger the volume of the receiving water and the shorter the turnover rate, the less sensitive the water body will be to an influx of pollutants. Volume and turnover rate are especially important in irrigated regions. If the base stream flow is large, the pollutant concentration which results after irrigation return flows have been mixed with the stream may not be large enough to adversely affect usage.

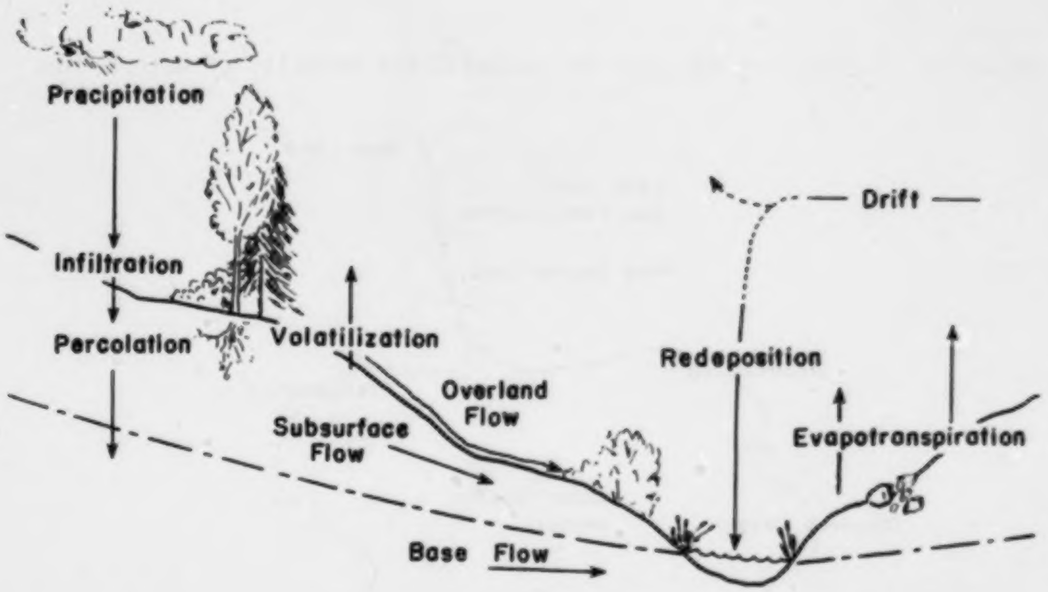
Figure 3. Factors influencing the assimilative capacity of waterbodies.



AGRICULTURAL NONPOINT SOURCE POLLUTANTS: FACTORS RELATED TO THEIR CONTROL

A nonpoint source control can be evaluated in terms of both the stage of the pollutant delivery process during which it is operative and the pollutant pathways it affects. A pollutant may undergo many physical and biological transformations between the time it becomes available in the field and the time it is delivered to a stream, lake, or groundwater reservoir. Substances initially strongly adsorbed to soil particles, for example, may later be detached and become dissolved in runoff waters. The transformations that a pollutant undergoes determines which pathway(s) it will take between cropland and receiving water. A pollutant can be moved suspended or dissolved in water, or attached to soil particles in overland or subsurface flows. Figure 4 illustrates the pathways pollutants may follow as they move to a water body.

Figure 4. Pollutant pathways.



Nitrogen

Although nitrogen (N) is naturally present in soils, it must be added to most croplands in order to increase their productivity. Manure spreading, application of commercial fertilizers, and incorporation of crop residues all contribute nitrogen to the soil. Not all of the nitrogen present on or in the soil at a given time is available for plant uptake. Organic N (primarily in particulate form) normally constitutes the bulk of soil nitrogen. It is only slowly converted to the more readily available inorganic forms of nitrogen (inorganic ammonium and nitrate).

Because of its mobility in soils, nitrate is the form of nitrogen most commonly used by plants. Plants may also use ammonium nitrogen as an additional source.

Nitrate-nitrogen is highly soluble and will readily percolate below the crop root zone. It may also be transported with surface runoff, but not generally in high concentrations. **Organic-nitrogen and ammonium, on the other hand, become adsorbed to soil and are lost primarily with eroding sediment.** Organic nitrogen generally converts to inorganic nitrogen with time, thus all transported nitrogen is a potential contributor to eutrophication.

Three microbial transformation processes relate to the control of nitrogen. The first two, ammonification and nitrification, are part of the mineralization process which converts nitrogen from its organic to its inorganic form, making it available for crop uptake. The last reaction, denitrification, causes nitrogen to be lost to the atmosphere. Denitrification may reduce the quantity of nitrogen lost via percolation and runoff, however, it also means that some fertilizer is wasted.

Nitrogen may be lost in the gaseous form by processes which do not require the presence of microorganisms and are strictly chemical. Such losses of nitrogen as ammonia can occur especially with heavy surface applications of urea or ammonium fertilizers.

Practices which cause anaerobic soil conditions promote denitrification, especially when accompanied by a source of soluble carbon to serve as an energy source for the denitrifying organisms. Such conditions are especially prevalent at waste application sites and beneath animal feed lots and corrals. Practices which increase either the oxygen content of the soil or soil drainage (to remove the products of mineralization) increase mineralization, thereby allowing more nitrogen to become available for plant growth or for leaching. Also, if fertilizers or manure are not incorporated into the soil, the potential for nitrogen loss via volatilization to the atmosphere and via surface runoff will be greater. Finally, **the timing of fertilizer and manure applications to meet crop needs is critical. The closer an application is made to the period of maximum crop growth, the smaller the potential for losses.** For example, the use of split applications, at time of planting and just before the peak growth period, is usually recommended.

Phosphorus

The total phosphorus (P) content of most soils is low, between .01 and .20 percent by weight (Brady, 1974). Since much of this phosphorus is unavailable for plant growth, manure and fertilizers are used to increase the level of available phosphorus in the soil. Some of this applied phosphorus can reach nearby water bodies with runoff and erosion. In addition, phosphorus that may be unavailable in the soil system may still erode with soil particles and become available when the bottom sediment of a stream or lake becomes anaerobic. It may then cause water quality problems. Estimating the potential impact of phosphorus loss on water quality is difficult at present, because the relationships between various forms of phosphorus in the soil and sediments, water, and biota are only poorly understood. The dynamics of phosphorus adsorption by bottom sediment are particularly ill-defined.

Phosphorus can be classified as either organic or inorganic. **Available inorganic phosphorus, which serves as the intermediary between the bulk of the total P, the organic P and the soluble fraction immediately available to the plant is of most concern.** Inorganic phosphorus can be either dissolved in surface or subsurface waters or associated with sediments (particulate). Although much of the particulate fraction acts as if it were permanently fixed by the soil, some of the particulate inorganic phosphorus (the labile fraction) serves as a source of the dissolved form. The labile pool is commonly several hundred fold larger than the soluble fraction at any point in time. The fracton of the total particulate inorganic phosphorus which is labile is generally not known. **The equilibrium between labile particulate and the dissolved inorganic phosphorus depends in part on the chemical and biological characteristics of the limnological system. The amount of dissolved phosphorus changes during transport from cropland to streams and lakes as well.**

Losses of particulate inorganic phosphorus from croplands occur via erosion since this form is associated with sediment. Rainfall events tend to cause a higher particulate phosphorus loading of streams than do snowmelt events because the former tend to be more erosive.

Although dissolved inorganic phosphorus is found in all surface and subsurface flows, a decrease in runoff may not necessarily decrease the rate of dissolved inorganic phosphorus loading to a particular stream or lake. Labile particulate inorganic phosphorus already present in the lake or stream sediments may continue to be converted to soluble form. In other words, a decrease in runoff may decrease total phosphorus loss but may have little short-term effect on the levels of available phosphorus in receiving waters. If the amount of pre-existing labile phosphorus in bottom sediments is small, however, then controlling runoff may reduce dissolved phosphorus concentrations and substantially improve water quality.

Sediment

Eroded soil may either be redeposited on the same field or transported from the field in runoff waters. Sediment is that soil which leaves a field and is subsequently deposited in streams, lakes, roadside ditches or other off-field areas. In nonirrigated regions, the sediment delivery process starts by the detachment of soil particles either as a result of raindrop impact or overland flow. Erosion can be classified either as interrill or rill erosion. Interrill erosion is that erosion caused mainly by raindrop impact and subsequent shallow flow toward rills. It is thus independent of slope position and occurs over relatively small areas. When the runoff from interrill areas becomes sufficiently concentrated, small but well-defined channels or rills are formed. Rill erosion can contribute substantially to suspended sediment loads since channelization of water increases flow velocity, which in turn increases the ability of the runoff to dislodge and transport soil particles. Gully erosion is an advanced stage of rill erosion where field operations are often impaired.

In irrigated regions, soil particles are detached both by raindrop or sprinkler drop impact, and by the surface application of irrigation water. Significant amounts of soil are eroded by the flow in irrigation furrows since the volume and velocity of such flows are relatively large. These flows not only contribute to the detachment process, but also provide the means for transport of detached particles. Because irrigation water percolates along the length of the irrigation furrow however, flow volume and velocity decrease and mid-field deposition of sediments eroded from the head of the irrigated field is common. Much of the sediment eroded from furrow-irrigated fields actually originates in the bottom 1/2 to 1/3 of the field, particularly if water velocity increases toward the end of the field as the streams approach a relatively deep return flow collection ditch.

Sediment from cropland usually contains a higher percentage of finer and lighter particles than the soil from which it originates. Although large particles are more readily detached from the soil surface because they are less cohesive, they will also settle out of suspension more readily. Clay particles and organic residues on the other hand, once detached, will stay suspended for longer periods of time and will be transported more readily in slower flowing water. They are thus apt to be transported for greater distances, and a larger portion of them will leave the field. **This selective erosion process can increase overall pollutant delivery, because small particles have a much greater adsorption capacity for other pollutants than do larger particles.**

The quantity and type of adsorbed pollutants in sediment is largely determined by the nature of the soil from which it originates, and the type of erosion. Rill and interrill erosion moves soil particles from the surface (plow) layer of the soil. Gully and streambank erosion can move particles that were part of the lower soil strata as well. Topsoil is usually richer in nutrients and other chemicals than the subsoil because of normal nutrient cycling in the soil profile and past fertilizer and pesticide applications. Topsoil is also more likely to have a greater percentage of organic matter. **Sediment originating from surface soils thus will have a higher total chemical enrichment than sediment from gullies or stream banks.**

Sediment delivery can be reduced by either controlling detachment or transport. Since clay and organic matter are easily transported, it may be easier to control these potential pollutants through practices that control detachment. Sands or coarse silt particles are very easily detached, thus

Animal Wastes

Manure is a source of organic matter, nutrients and pathogens. **Manure applied on the soil surface will be more easily lost in runoff than manure incorporated into the soil.** As discussed in the sediment section, organic matter is not easily detached from the soil surface because of its cohesive properties, but it is easily transported because of its low density. Therefore, **practices which control detachment will probably be more effective in reducing the loss of organic matter than practices which control transport.**

Losses of manurial organic matter can also be reduced by controlling the rate, location, and timing of applications.

Although animal diseases may be transmitted to humans through contact with animal feces, applied manure is rarely a public health problem. The pathogens present in manure are filtered by soil particles and rarely infiltrate farther than a few centimeters into the soil profile. Consequently, fecal ground water contamination is usually not a problem following animal waste application to soil. Although erosion and runoff can detach manure particles and transport them to streams and lakes, the number of pathogenic organisms reaching surface waters is generally limited and their survival rate low. Low soil moisture levels, low pH values, high temperatures, and direct solar radiation can all cause pathogenic populations to decrease rapidly with time. Manure storage facilities may represent an exception, since the manure-slurry environment enables the survival of many organisms. Composting of the wastes prior to application is normally quite effective in decreasing the numbers of active pathogens in the material.

Two aspects of animal waste disposal that have received special attention are problems related to runoff from barnyards, and winter spreading of manure. Both are suspected to be relatively concentrated sources of nutrient loading to surface waters. Barnyards are areas of intensive use by livestock characterized by the absence of vegetative cover and the presence of appreciable accumulations of manure. Direct runoff through the barnyard from upland drainage areas and direct precipitation on the barnyard will detach and transport animal wastes from the disposal area. The wastes contain nutrients, and in addition, are characterized by high biological oxygen demand (BOD) and nitrogenous oxygen demand (NOD), thus if delivered to a water body, will impact water quality.

Spreading manure on frozen ground or snow cover can lead to relatively high concentrations of nutrients during subsequent runoff events. Such high losses have been generally associated with critical periods such as spreading on saturated ground after a rainfall, or on actively melting snow.

Salinity

The accumulation of salts in agricultural soils is an undesirable consequence of supplying the land with irrigation water needed to sustain or enhance agricultural production. Since irrigation water is generally derived from ground water supplies or river sources, it has a natural (base) load of dissolved salts. **As irrigation water is consumed by the plants or lost to the atmosphere via evaporation, salts (and other pollutants) remain in the soil.** High salt concentrations are created within the soil profile, especially in the root zone where most water removal occurs. Salt crusts may form on the soil surface between irrigation furrows or where the land is left fallow, and **accumulations of soluble and exchangeable sodium lead to soil dispersion and structure breakdown.** Increases in soil and water salinity can be quite substantial, since 70 to 80 percent of the applied water is lost through evapotranspiration. Fortunately, a tripling or quadrupling of the salt concentration of most irrigation waters still leaves soil solutions which are not lethal to the growth of normal crop plants.

In order to maintain productivity in irrigated agriculture, accumulated soil salts must be moved periodically below the root zone to prevent the impairment of plant growth. Therefore, **the quantity of water diverted for crop use must exceed actual plant water requirements to allow for the leaching of these soluble salts. Although this procedure promotes improved plant growth, it also increases the environmental impact of irrigation by increasing the transport of salts and mobile nutrients (e.g. nitrate) to receiving waters.** As excess water percolates downward, its salt load is increased by the leaching of natural salts arising from soil mineral weathering, atmospheric deposition, or former marine or lacustrine (lake-deposited) substrata. If the quantity of leaching water is not excessive, some salts may react with other ions in the soil and precipitate, lowering once more the salt load of the percolating waters.

Seepage losses from unlined delivery canals and laterals are high in many irrigated areas. The combination of these seepage losses and deep percolation losses can cause groundwater levels to rise near the soil surface (water logging). Water and salts are supplied to the root zone by upward movement of groundwater due to capillarity. The water moves to the soil surface and evaporates, leaving its salts behind. This process can result in extensive soil salination if allowed to operate for any appreciable length of time.

Irrigation return flows provide the vehicle for conveying accumulated soil salts to receiving streams or groundwater reservoirs. If the salt concentration of the return flow is small in comparison to total river flow or groundwater capacity, water quality may not be degraded to the extent that use is impaired. However, **the process of withdrawing water for irrigation and the return of saline water is frequently repeated many times along the course of a river. Eventually, the salt concentration of the water can become high enough to impair water use for irrigation or other purposes.**

Salinity control is complicated because salts are present both in receiving waters and in contributing soils, and also because control practices may interfere with crop production. The quantity of irrigation water should not be decreased without increasing the efficiency of application, if the level of production is to be maintained. **Generally, salt problems from irrigated agriculture can be most effectively dealt with by increasing the efficiency of irrigation.**

In summary, consideration of the physical and chemical characteristics of pollutants is the basis for the design of control measures. An effective practice is one which prevents the delivery of a pollutant to a water body by controlling the availability of a pollutant in the field, its detachment, or its transport to a receiving body of water. The extent to which a measure controls a pollutant pathway will often be dependent on physical variables such as precipitation, soil type and topography.

SECTION 3

NONPOINT SOURCE CONTROL PRACTICES

CRITERIA FOR GROUPING NONPOINT SOURCE CONTROLS

The control of nonpoint source pollution ultimately involves the selection and design of practices on a site-specific basis. Before this is done, however, candidate practices must be identified and screened. Candidate BMPs are grouped in this section according to pathway control mechanisms and practice permanence to serve as an aid in preliminary design stages. Both of these grouping criteria are compatible with NPS evaluation and analysis methods described in Section 4.

Source and Pathway Control Mechanisms

Pollutants may be controlled at their source or point where they become available, during detachment, or during transport. **Source control of pollutants, if practical, can be a very efficient form of control. Source control is the management of a potential pollutant when placing it in the field environment.** Crop nutrient and pesticide management practices are examples of practical and efficient source controls.

Control mechanisms which act during detachment and transport are also effective in reducing pollutant delivery. **Practices which control the soil eroision and sedimentation process will be effective in controlling pollutants that are strongly adsorbed to soil. Practices which control overland flow and subsurface flow will be effective in controlling weakly adsorbed and non-adsorbed substances. Examples of pathway control practices are contour farming and conservation tillage.**

Practice Permanence

Given the lack of water quality monitoring data, data quantifying edge-of-field losses, and data quantifying losses between field and stream or lake, controls considered should be conservative. **Nonstructural practices which are of relatively low cost to landowners and are related to efficient use of farm resources should be given emphasis in the early stages of NPS planning and implementation activities.** As the NPS program evolves, land management practices which are more intensive and permanent may be required. This sequence of practice selection is analagous to the point source control program where treatment processes have evolved over the past sixty years from primary to secondary and tertiary treatment levels.

Candidate measures can be grouped according to their degree of permanence into three types of practices: management, vegetative, and structural. Management practices involve changes in timing, chemical application rates, and tillage systems. They usually do not involve separate field activities.[1] Crop rotations and area devoted to each crop remain constant; only certain farm management decisions are affected. Vegetative practices involve changes in cropping systems. They generally must be renewed annually. Structural practices necessitate capital investment and construction activities. The risks may be high because of this initial investment. Once implemented, structural practices can affect farm production for substantial periods of time. However, they also assure more permanent pollution control.

CANDIDATE MEASURES FOR THE CONTROL OF NONPOINT AGRICULTURAL SOURCES

Soil and water conservation practices (SWCPs) were originally designed to conserve the land resource rather than to control water pollution. They represent candidate measures for the control of agricultural nonpoint source pollutants, since losses of these pollutants are always associated with soil water movement or erosion. There is a tendency to use SWCPs as best management practices since these practices are already familiar to most farm operators and there is an established institutional framework. This section will include a discussion of 1) those SWCPs that double as potential water quality improvement practices, and 2) some additional measures which may be used to control agricultural nonpoint source pollutants.

The following discussion of candidate measures has been divided into two sections: those practices relevant to nonirrigated agriculture, and those concerned with irrigated agriculture. Although certain candidate measures are applicable to both systems, irrigated agriculture has unique pollutant control options because water application is controlled. Many candidate measures applicable to nonirrigated agriculture are ineffective or unnecessary on irrigated lands. **Practices discussed in the two sections are grouped according to the management, vegetative, and structural control categories related to practice permanence. Within these categories, practices are further grouped, although not explicitly, according to affected pollutant pathways.**

NONIRRIGATED AGRICULTURE

Precipitation quantity, intensity, and seasonal distribution are significant determinants of pollutant loading. Control or manipulation of these factors are not current options for farmers. Wastewater collection and treatment are also generally impractical due to the diffuse nature of runoff flows from nonirrigated fields.[2] Table 2 lists some general candidate control measures for nonirrigated agriculture according to the three categories: management, vegetative, and structural.

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[1] Exceptions are split applications of fertilizers and pesticides.

[2] The exceptions are, livestock waste collection and storage systems.

TABLE 2. CANDIDATE MEASURES FOR NONIRRIGATED CROPLAND

Candidate Measure		Description	Pollutant Impact *									
			T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
Managerial Controls												
NIA-1	**Reducing Excessive Application Rates**	Commercial fertilizer application rates should match crop needs accounting for manure applications, soil mineralized nutrients and losses by leaching, runoff, volatilization and denitrification. Pesticide applications should be based on pest populations and anticipated crop losses.	-**	-	-	-	-	-				
NIA-2	**Improved Timing of Application**	Crop nutrient applications should be timed to correspond with crop uptake. Insect life cycles should be accounted for when planning pesticide applications.	-	-	-	-	-	-				
NIA-3	**Improved Method of Application**	Soil incorporation of manure, commercial fertilizers and pesticides will decrease potential losses. Aerial applications of pesticides should account for wind and temperature conditions.	-	-	-	-	-	-				
NIA-4	**Improved Timing of Field Tillage Operations**	Minimizing fallow periods and increasing soil incorporation of nutrients, manure and pesticides are important elements of this practice.	-	-	-		-	-				
NIA-5	**Using Alternative Pesticides**	Whenever possible, the pesticide with the least potential for water quality degradation should be used. In general, persistent, soluble and/or highly toxic pesticides have the greatest potential to degrade water quality.					-	-				
NIA-6	**Using Insect-and-Disease-Resistant Crop Varieties**	Planting crop varieties which have increased resistance to insects and plant diseases reduces the need for pesticides.					-	-				
NIA-7	**Optimizing Time of Planting**	Planting and harvesting crops at optimal times based on life cycle of pest.					-	-				
NIA-8	**Using Mechanical Weed Control Methods**	Cultivating for weed control rather than use herbicides.	0/+	0/+	0/+	0/+	-/0	-				0 -

(Continued)

TABLE 2. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
NIA-15 Contour Strip Cropping (Cont.)	If the sod is a grass- legume mixture, additional nitrogen will be supplied requiring less fertilizer application.			0/-	0/-						
NIA-16 Permanent Vegetative Cover	If potential pollutant flux is high and other practices are not applicable a continuous sod cover will increase infiltration and greatly reduce erosion.	-	-	-		-	-				
NIA-17 Field Borders and Grass Filter Strips	If pollutants are not controlled adequately at source, grass strips that function as filters can be placed at field edges. The effectiveness of this practice is dependent on the velocity and depth of flow entering the sod area, the topography and the width and quantity and quality of plant cover in the grassed area.	-		-		-					-
NIA-18 Buffer Strips Along Streams	Similar to the above practice (Grass Filter Strips and Field Borders) however, it is generally further from the sources of pollution.	-		-		-					-
Structural Controls											
NIA-19 Terraces	Used to change the slope and effective slope length of the land and pond runoff water. Principly they follow the land contours but, most are graded slightly to allow some runoff. Applicable only on deep soils and on long slopes.	-	-	-	+		-				-
NIA-20 Diversions and Interception Drains	Diverts runoff originating above a field and Shortens the effective slope length of the field.	-	0/+	-		-	0/+				-

(Continued)

TABLE 2. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
NIA-21 Grassed Waterways	Sod channels provide a non erosive outlet for runoff from contours, graded rows, terraces or diversions.										

* T-P: absorbed phosphorus (total and labile)
NA-P: nonabsorbed phosphorus(soluble forms)
T-N: absorbed nitrogen (total N and ammonium)
NA-N: nonabsorbed nitrogen (nitrate)
A-Pes: absorbed pesticide
NA-Pes: nonabsorbed pesticide

** + Increases in application of control will increase pollutant losses
- Increases in application of control will decrease pollutant losses
0 No appreciable effect

Management Controls

Reducing Excessive Chemical Application Rates (NIA-1)--

If fertilizer is not a major production cost relative to other inputs, it is often applied in excess to insure maximum yields. Fertilizer rates **however, should be based more closely on crop needs, taking into account the residual nitrogen content of the soil, past nitrogen additions (from legumes, manures, and commercial fertilizer applications) and prior and anticipated nitrogen removal (to crops, in deep percolation, through denitrification, or with eroding soil).** If all these components are considered in a nutrient budget, a fair estimation of present nitrogen needs can be made. Manure and manure handling systems directly affect the nutrient (and especially nitrogen) content of wastes, and therefore manurial nutrient content should be estimated before developing a land application schedule.

Pesticide requirements vary from year to year, depending on climate, insect and weed populations, and other factors. Consequently, application rates of pesticides may at times also exceed what is needed, particularly for high value crops where financial losses can be large if pests are not controlled.

Timing of Application (NIA-2)--

Applying nutrients and pesticides at times when they are most needed by the crop can be very effective in reducing pollutant losses. Fall fertilizer applications of nitrogen can be completely leached below the crop root zone before the growing season begins in areas of considerable winter precipitation. Early spring applications can also result in appreciable losses if heavy rainfall follows. The availability of machinery and labor has a marked influence on fertilizer application schedules. Also, crop cover may limit fertilizer applications during the growing season. Fall applications, where necessary, should utilize ammoniacal (NH_4) nitrogen to minimize leaching, and should be applied after the soil has cooled to less than approximately 50°F to prevent microbial conversion to the mobile nitrate formed during warm fall weather.

Pesticides should be applied to achieve maximum effectiveness and minimum loss. Insecticides, for example, are more effective at particular stages of a pest's life cycle and applications can be timed accordingly. In areas where pesticides are used extensively, the timing of applications can be linked to weather forecasting. Critical periods when even extremely low concentrations can influence fish spawning should be avoided.

Improved Method of Application (NIA-3)--

The incorporation of manure and fertilizers in the soil reduces losses. Incorporation can control losses in surface runoff (especially for early spring applications when rainfall events closely follow fertilizer application). Incorporation also makes nutrients more available to plants and reduces volatilization losses by nitrogen, thus increasing the efficiency of application. The method of applying pesticides can also strongly influence potential losses. Pesticide losses through drift and volatilization can occur with aerial applications of some pesticide formulations or with certain types of spray equipment.

Improved Timing of Field Tillage Operations (NIA-4)--

The timing of tillage operations can markedly affect pollutant delivery. If the soil is tilled soon after chemicals have been applied, the quantities of those chemicals lost in surface runoff can be reduced. While those fields having a low sediment delivery potential can continue to be fall plowed, those with high sediment delivery potentials should probably be plowed in the spring, or a form of reduced tillage considered where possible.

Using Alternative Pesticides (NIA-5)--

The persistence, adsorption characteristics, toxicity, form, and method of application all interact to determine the effect a pesticide will eventually have on water quality. In general, persistent, soluble, and/or highly toxic pesticides have the greatest potential to impact water quality.

By alternating pesticides, the effectiveness of each application can in some cases be increased, the amount needed reduced, and development of resistance among the insect or weed population minimized. Biological control and integrated pest management programs (combinations of biological, chemical, and cultivation control) have gained popularity in recent years.

Using Insect-and-Disease-Resistant Crop Varieties (NIA-6)--

If a crop is more resistant to disease and insects, it will require less application of insecticides and herbicides. Although yields may be somewhat less for such varieties, the decrease in cost of chemicals may compensate somewhat for the decreased production. These resistant varieties may be useful in combination with other practices, such as reduced tillage or zero tillage, which might otherwise require additional pesticides.

Optimizing the Time of Planting (NIA-7)--

Insect or disease damage can sometimes be reduced, and/or pesticide application rates decreased, if a crop is planted at the appropriate time. The life cycle of the pest will determine appropriate planting dates in such situations. In some cases, it is advantageous to plant the crop at the earliest possible date. This is generally true, for example, in dealing with many of the plant diseases found in the nation's extensive winter wheat crop.

Using Mechanical Weed Control Methods (NIA-8)

Employing mechanical methods to control weeds will decrease the need for herbicides, but labor and machinery costs will be increased. In addition, these methods may damage soil structure. Pulverization of the soil can lead to decreased infiltration, increased erosion, and increased losses of sediment and associated chemicals. Creation of "tillage pans" due to increased compaction can decrease crop root penetration and nutrient uptake by crops.

Reduced Tillage Systems (NIA-9)--

Conventional tillage can destroy intrinsic soil structure, decrease infiltration, and increase surface runoff. It also incorporates most crop residues into the soil, leaving the surface exposed to raindrop impact and to maximum runoff energy. **Reduced tillage systems include a spectrum of practices, from conventional moldboard plowing with fewer land smoothing operations to minimum soil disturbance.** The effectiveness of these practices does not depend as much on the tillage operations per se, but rather on the amount of surface residue remaining on the field following tillage. **The increase in surface residue reduces the loss of sediment, and hence the loss of soil-associated nutrients and pesticides.** It also assists markedly in wind erosion control. The increased mulch and improved porosity of the surface associated with reduced tillage, also significantly increases infiltration. Deep percolation losses of nitrate and of mobile pesticides may actually be increased by this practice in some cases. Reduced tillage can be used for most fields where crop seedbed preparation is needed. Limiting physical factors in the suitability of reduced tillage systems are climate and soil drainage. A higher variabilty in crop yield (and, thus higher risk to the farmer) can be expected than with conventionally tilled fields.

No Tillage systems (NIA-10)--

No tillage (or zero-tillage) is most adaptable to well drained soils in areas where the length of growing season is relatively long. As with reduced tillage, no till is very effective in reducing surface runoff and controlling soil erosion. However, additional pesticide applications may be needed to control weeds or insects which would not be needed with conventional or reduced tillage systems. An even greater variability in crop yield is evident for no-till planting than for forms of reduced tillage.

Contour Farming (NIA-11)

Tillage and planting operations which follow hillside contours increase surface storage and water, increase infiltration and decrease runoff, sediment, and total pollutant losses. These practices are generally not implemented on poorly drained soils, and are difficult to implement if the topography includes complex slopes. They have little effect on level land, on slopes greater than 12%, or on slopes longer than 130 meters. Intense storms may break across the contoured rows and greatly reduce the effectiveness of contouring. Contouring may also be more difficult when wide equipment is employed.

If tillage and planting operations are performed across the field slope but not on the contour, it is sometimes referred to as graded rows. The slope of the grade is usually less than 1 percent. **The effects on water**

conservation, soil erosion and control of pollutant pathways are similar to contour farming. Although graded rows would affect pollutant movement less than contouring, where soil drainage is a problem this practice acts as a compromise measure.

Vegetative Controls

Meadowless Rotations (NIA-12)--

Crop rotations can be effective in reducing the need for pesticides, since insect population cycles will be disrupted if host crops are eliminated from the local area. In particular, by employing a meadowless rotation, different high value row crops can be continuously grown in an area, and certain insect pests controlled or eliminated as well. For example, a corn-soybean rotation is commonly used in areas of the midwest where corn rootworm persists. The rotation not only breaks the insect life cycle but the nitrogen-fixing soybean decreases nitrogen requirements for the subsequent corn crop.

Sod-Based Rotations (NIA-13)--

Sod benefits the soil in many ways. It improves soil structure, which in turn increases infiltration and decreases surface runoff. It can also reduce the amount of fertilizer needed for following row crops because grass-legume sods act as a source of nitrogen.

Winter Cover Crops (NIA-14)--

Crops which cover a field during all or part of the nongrowing season influence pollutant loss in two ways. First, **increased crop cover and surface residue decrease soil erosion by water and wind.** Second, **a well established winter cover crop can take up nutrients which would otherwise be lossed via overland flow, erosion (from rainfall and snowmelt events) or leaching.** The main disadvantage of the practice is that the winter cover crop usually must be seeded in the early fall, amd plowed under or chemically killed in the spring. This requires more labor, fuel, seeds and chemicals for the overall farm operation.

Contour Strip Cropping (NIA-15)--

If greater effectiveness is needed than can be achieved by contour cropping alone, alternating contour strips of row crops with strips of sod can further reduce soil losses and associated pollutants. This practice is particularly useful on long slopes or in areas of particularly erosive rainfall. In these situations, surface flow can accumulate enough energy to render normal contours ineffective. By reducing the rate of surface flow and increasing infiltration, soil detachment is decreased and surface storage of water is increased. In sod-covered areas, the soil is protected from raindrop impact, so fewer soil particles are detached from the surface. Soil structure is also improved, and nitrogen is added to the soil if a legume is included as part of the mixture.

Permanent Vegetative Cover (NIA-16)--

If the potential for pollutant loss from a particular field is high and there is no other cost-effective management practice available, it may be necessary to leave the field grass-covered on a permanent basis. This protects and stabilizes the soil, and decreases surface runoff and erosion.

Field Borders and Grass Filter Strips (NIA-17)--

If pollutants are not being controlled adequately at the source, **grass strips** can be placed at field edges. These areas **function as filters where sediments and associated pollutants become trapped. Potential pollutants can then either decay, infiltrate the soil and/or be taken up during plant growth.** In order for the areas to be effective, they must slow the rate of run off sufficiently to allow some of the sediment-borne pollutants to be removed. The effectiveness of a field border or grass filter is dependent on the velocity and depth of flow entering the sod area, the topography, the width, and the quantity and quality of plant cover in the grassed area.

Buffer Strips Along Streams (NIA-18)--

Buffer stips along streams serve the same function as field borders, but are generally farther from the source of pollution. Again, the characteristics of the buffer strip and of the runoff water passing over the buffer strip determine the settling rate of pollutants and hence, the efficiency of the control practice.

Structural Controls

Terraces (NIA-19)--

Terraces can be used to change the effective slope length of the land. Most terraces are graded to facilitate runoff. Runoff may be routed to grassed waterways or to ponding areas where it can be discharged through a tile system (PTO terraces). **Although terraces do not significantly reduce losses of mobile pollutants and may increase infiltratation somewhat, they effectively reduce erosion losses to less than 10 percent of losses incurred with up-and-down hill farming.** Terraces primarily reduce soil loss and associated pollutants by decreasing runoff velocities. Terraces are generally appropriate on fairly deep soils and long slopes of less than 12 percent. Their initial cost is high.

Diversions and Interceptions Drains (NIA-20)--

Runoff originating above a field can often be diverted away from that field. Such **diversions shorten the effective slope length of the field, decreasing soil detachment caused by surface flow.** Any pollutant reaching a diversion ditch, however, is also more likely to reach a stream. Diversions can be useful for protecting fields that are highly erosive or that are particularly hazardous because of high chemical application rates. Subsurface diversions (interception drains) can prevent the movement of subsurface flows.

Grassed Waterways (NIA-21)--

Stabilizing channels with sod can greatly reduce the amount of erosion occuring within the channels. This practice is commonly used where channels remove runoff from contoured or graded rows, or from terraced channels.

Subsurface Drainage (NIA-22)--

The principal water quality benefit of subsurface drainage systems is increased soil water capacity. By lowering the water table and increasing percolation, lower antecedent moisture conditions can reduce runoff. For soils with low permeability, or during high intensity storm events, however, the influence of tile drains on runoff is greatly diminished.

For repeatedly wet soils, subsurface drainage may improve plant growth, which in turn may reduce surface runoff and erosion. The net result, however, may be an increase in nitrate losses from the area due to a reduction in denitrification associated with anaerobic conditions.

Detention Ponds (NIA-23)--

Detention ponds collect runoff from agricultural fields. They **enable sediments, and pollutants adsorbed to the sediments to settle out of solution.** Available phosphorus and nitrogen can then be taken up by aquatic plants and non-persistent pesticides will have an opportunity to degrade before the water is released.

IRRIGATED AGRICULTURE

In arid regions, the timing and intensity of water applications are determined by the irrigation method. Deep percolation and runoff losses can be reduced by controlling various aspects of the irrigation system. Table 3 lists some of the measures that can be used to decrease pollutant loading from irrigated fields.

Many of the soil and water conservation practices for nonirrigated agriculture listed in Table 2 are not compatible with irrigated agriculture. For example, grassed waterways are not utilized in arid regions because of the water demand associated with them, and because of the removal of valuable irrigated land from production.

Current legal and institutional mechanisms for allocating water between irrigation districts and farms are responsible for much of the inefficiency of irrigation, and associated pollution. Institutional changes should thus be viewed as primary control mechanisms. Most institutional controls, however, should generally be considered only relative to a longer planning horizon.

TABLE 3. CANDIDATE MEASURES FOR IRRIGATED CROPLAND

Candidate Measure		Description	Pollutant Impact									
			T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
Managerial Controls												
IA-1	Reducing Excessive Chemical Application Rates	see NIA-1		-**	-	-	-	-				
IA-2	Improved Timing of Chemical Application	see NIA-2		-	-	-	-	-				
		Sprinkler and trickle irrigation both are suited to well timed fertilizer applications.										
IA-3	Improved Method of Chemical Application	see NIA-3		-	-	-	-	-				
IA-4	Using Alternative Pesticides	see NIA-4					-	-				
IA-5	Using Insect-and-Disease-Resistant Crop Varieties	see NIA-6					-	-				
		Using salt tolerant crops so less leaching of salts is necessary.		-/0		-		-/0	-			
IA-6	Optimizing the Time of Planting	see NIA-7					-	-				
IA-7	Using Mechanical Weed Control Methods	see NIA-8	0/+	0/+	0/+	0/+	-/0	-/0	0/+			+

(Continued)

TABLE 3. Cont'd

Candidate Measure		Description	Pollutant Impact									
			T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
IA-8	Appropriate Timing and Choice of Tillage Operations	Deep tillage may be required to optimize salinity removal and for efficient irrigation applications.				+			+			
		Use tillage to incorporate fertilizer into soil. However, excessive tillage can increase evaporation losses.		-	-	-						
IA-9	Reduced Tillage Systems	Each tillage operation on furrow irrigated land increases sediment losses. Reduced and no-tillage systems can reduce these losses.	-		-		-					-
IA-10	No-Tillage Systems											-
		For wind erosion control residue left from reduced or no-tillage is superior to early frequent irrigation maintaining soil moisture.	-	-	-	+/0	-	-	+/0			-
IA-11	Contour Farming	see NIA-11	-	-	-	+	-	-	+			-
IA-12a	Improved Water Management: Call Period or On-Demand Water Ordering	Water allocations should be sufficient but not excessive. A call period (a minimum length of time allowed to place an order) would facilitate better scheduling and planning.	-	-	-	-	-	-	-			-
		On-demand water ordering maximizes scheduling flexibiblty however, this encourages less planning.	-/0	-/0	-/0	-/0	-/0	-/0	-/0			-/0
IA-12b	Improved Water Management: Irrigation Scheduling	Irrigation scheduling services utilize meteorological information with soil moisture levels to forecast future irrigations. Pesticide and fertilizer recommendations can also be made through this service.		-	-	-	-	-	-			-

(Continued)

TABLE 3. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
IA-13 Conveyance Channel Improvements and Maintenance	Keeping canals free of silt deposits allows for improved water control. Controlling aquatic vegetation maintains canal capacity, reduces evapotranspiration and prevents clogging at control structures. The repair of damaged canal banks prevents erosion and seepage.	-	-	-	-	-	-	-			-
IA-14 Improved Management of System Storage	System water storage provides flexibility and efficiency but, it should be minimized to reduce seepage and evaporation.	-	-	-	-	-	-	-			-
	The coordination of the use of stored and excess water with downstream users.										
IA-15 Improved Management of Return Flows	Canals should not be operated at capacity at all times with unneeded water spilled into return flows.				-			-			
IA-16 Land Retirement	Discontinuation of irrigation in critical areas.	-	-	-	-	-	-	-			-
Vegetative Controls											
IA-17 Crop Rotations	see NIA-12 and NIA-13										
IA-18 Winter Cover Crops	Crops which cover a field during all or part of the nongrowing season in sandy areas protect the soil from wind erosion and from erosion by early season irrigations.	-		-		-					-
IA-19 Field Borders and Buffer Strips	see NIA-17 and NIA-18	-		-		-					-
	For furrow irrigation, for which the use of field borders is common, erosive crops such as potatoes and close growing crops such as alfalfa don't effectively trap sediment however, double- and triple- planted wheat has been effective.	-		-		-					-

(Continued)

TABLE 3. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
Structural Controls											
IA-20 Diversions and Interceptor Drains	Diversions direct runoff originating above a field away and it shortens the effective slope length of the field. However, pollutants reaching diversions are more likely to enter a stream.	-	0/+	-		-	0/+				-
IA-21 Land Leveling	Used to prepare land for furrow or border irrigation. If it is leveled to a constant grade, irrigation uniformity and efficiency can be increased.		-		-		-	-			
	Also, leveling can be used to convert convex slopes to concave slopes inorder to promote on-field deposition of eroded sediment.	-		-		-					-
	However, land leveling can create soils of poor chemical and physical property.	-	-	-	+	-	-	+			-
IA-22 Retention Ponds	Trapping sediment after it erodes from cropland and before it reaches a stream is an effective water improvement measure.										
IA-23 Seepage Control	Lining canals, ditches, laterals and water courses that have high seepage losses with some impermeable material reduces salt and nitrate losses.							-			
IA-24 Flow Measurement and Control	Measure and control flow to ensure adequate application of water while preventing unnecessary and wasteful diversions. To control the flow of water in canals and ditches structures such as: checks, drops, culverts and field inlet devices are used. To measure the flow of water use notched weirs or small fiberglass flumes.	-	-	-	-	-	-	-			-

(Continued)

TABLE 3. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
IA-25a Cutback Irrigation	In this method the flow volume is adjusted by using a head ditch or delivery pipe which is adjusted so that a flow is quickly introduced to the end of the furrow and then "cutback" to a "soaking" flow rate. This is done, among other reasons, to increase uniformity of application and reduce tailwater runoff. However, this method is only applicable if there is sufficient cross slope.	-	-	-	-	-	-	-			-
IA-25b Gated Pipe System	This method combines the features of the improved furrow and cutback systems and can be automatically controlled and coupled with on-demand water availability.	-	-	-	-	-	-	-			-
IA-25c Multi-set Irrigation System	This method combines features of the improved furrow system with a shorter length of run by using lateral supply pipes across each field. The system can be automated.	-	-	-	-	-	-	-			-
IA-26 Tailwater Reuse System/ Subsurface Drainage	If underlying strata are sufficently permeable use tile drainage to lower watertable and to facilitate salt movement from the rootzone.				-			-			
	Also, tile drainage allows collection of surface flows into a water drainage system for control.	-	-	-	-	-	-	-			-

(Continued)

TABLE 3. Cont'd

Candidate Measure		Description	Pollutant Impact									
			T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
IA-27	Tailwater Reuse System/ Pump Drainage	If the ground water is of good quality (not too saline), pumps can be used to lower the watertable and this water can be reused for irrigation.										
		If the ground water isn't of good quality it, after being pumped from the soil, can be treated.				-			-			
IA-28	Level Furrows or Diked Basins	For flat landscapes and relatively deep soils fields can be leveled and diked at one end to prevent surface runoff and improve uniformity of irrigation application.	-	-	-	-	-	-	-			-
IA-29	Sprinkler Irrigation	This system of irrigation includes: side-roll, center-pivot, tow-line and solid-set sprinklers. Sprinkler systems are more efficient than surface irrigation.	-	-	-	-	-	-	-			-
IA-30	Trickle Irrigation	With this system water is delivered to individual plants through lines or emitters in order to provide crop plants with nearly optimal soil moisture.	-	-	-	-	-	-	-			-
IA-31	Collection, Treatment and Disposal of Return Flows	If subsurface and surface return flows are too brackish for further use they can be collected disposed of or treated. For treatment,reverse osmosis and electrodialysis are two desalination processes. For disposal,deep well injection and evaporation ponds are examples.							-			

(Continued)

TABLE 3. Cont'd

Candidate Measure	Description	Pollutant Impact									
		T-P	NA-P	T-N	NA-N	A-Pes	NA-Pes	Salts	BOD	Path	Sed
Institutional Controls											
IA-32 Tax on Farm Inputs	Farmers can be charged in excess of the market price for fertilizer, pesticides or water inorder to encourage more efficient use of farm inputs.	0/-	0/-	0/-	0/-	0/-	0/-	0/-			0/-
IA-33 Discharge Regulation	Monitoring return flows from farms and from this estimate the pollutant discharges. Loading limits can then be established.	0/-	0/-	0/-	0/-	0/-	0/-	0/-			0/-
IA-34 Regulating Farm Inputs	Reasonable estimates of the crop's nutrient and water needs can be made. Consequently, water and nutrient application can be regulated directly.	0/-	0/-	0/-	0/-	0/-	0/-	0/-			0/-

* T-P: absorbed phosphorus (total and labile)
NA-P: nonabsorbed phosphorus (soluble forms)
T-N: absorbed nitrogen (total N and ammonium)
NA-N: nonabsorbed nitrogen (nitrate)
A-Pes: absorbed pesticide
NA-Pes: nonabsorbed pesticide

** + Increases in application of control will increase pollutant losses
- Increases in application of control will decrease pollutant losses
0 No appreciable effect

Management Controls

Reducing Excessive Chemical Application Rates (IA-1)--

As discussed in the section on nonirrigated agriculture, tailoring nutrient applications to crop nutrient needs can minimize nutrient loading to streams. Pesticide application rates should also match estimated needs with due consideration given to economic risks and uncertainties.

Improved Timing of Chemical Application (IA-2)--

Fertilizer application should not be followed by excessive water application. This practice assures maximum nutrient uptake and minimum nutrient losses via deep percolation and surface runoff. Fertilization in fall or winter should be avoided if possible since large leaching losses of nitrate can occur with winter rainfall. Irrigation techniques, such as sprinkler or trickle irrigation, are well suited to tailoring fertilizer applications to crop needs, for they enable farmers to apply a mixture of fertilizer and water throughout the growing season.

Improved Method of Chemical Application (IA-3)--

Refer to the nonirrigated section above for a discussion of incorporation (NIA-3). **Application through the sprinkler or trickle irrigation lines offers considerable promise in certain areas,** though fertilization rates must be modified from traditional levels, and better estimates of localized salinity effects associated with such practices are needed. Sprinkler-applied pesticides or fertilizers must not be applied excessively to portions of the field where sprinkler patterns overlap, and must be flushed from the lines before the lines are allowed to drain as pressurization eases at the end of the sprinkler operation.

Using Alternative Pesticides (IA-4)--

Refer to nonirrigated section above (NIA-5).

Using Insect and Disease-Resistant Crop Varieties (IA-5)--

Besides using crops that are resistant to insects and diseases (as discussed in the nonirrigated section), salt tolerant crops can also be grown. This reduces the need for excessive water appliation to remove salts from the root zone. Total salt and nutrient losses (both from subsurface and surface flows) will thus be reduced, with only a slight decrease in production if any.

Optimizing the Time of Planting (IA-6)--

Time of planting is often more flexible for irrigated than for nonirrigated agriculture. Early planting of warm season crops in cold climates should be avoided if it results in a long period of near-dormancy, or when added nutrients can leach and/or be eroded from the unprotected soil surface. Refer to the nonirrigated section for additional discussion (NIA-7).

Using Mechanical Weed Control Methods (IA-7)--

Refer to the nonirrigated section above (NIA-8).

Appropriate Timing and Choice of Tillage Operations, Reduced Tillage Systems and No Tillage Systems (IA-8, IA-9, IA-10)--

Proper cultural practices are important if crops are to be grown successfully in hot, dry regions. This is especially true under irrigated conditions, where weed and insect pests proliferate. To optimize both salinity removal from the root zone and efficiency of irrigation applications, deep tillage may be required to permit greater percolation, greater water storage capacity, and deeper root penetration into less permeable soil layers. Tillage operations also incorporate surface-applied fertilizers into the soil, reducing volatilization losses and making the fertilizer more available for plant uptake. This process also tends to decrease nutrient leaching losses by increasing the degree of contact between nutrients and the soil. Excessive or unnecessary tillage, however, can be detrimental to soil structure (resulting in crusting, for example) and can increase evaporative losses at times when crop moisture demand is high.

Each tillage operation on furrow-irrigated fields increases sediment losses, so decreased tillage of such fields is often desirable. Reduced and no tillage (zero tillage) systems decrease detachment of soil by raindrop impact and overland flow. For wind erosion control they are required in many irrigated areass. The alternative, frequent early-season irrigations to keep the soil surface moist, leads to excessive erosion and deep percolation of nitrates. Although surface residues are effective in reducing erosion from irrigated fields, some problems in controlling furrow flow rates and in obtaining adequate uniformity of application may result from residue accumulation in furrows. Thus, the advantages of water conservation and sediment control may be offset somewhat by decreased efficiency in irrigation water application.

Contour Farming (IA-11)--

Contouring is generally not applicable in irrigated areas, although contour irrigation is frequently proposed in furrow-irrigated areas with steeply sloping fields. Limitations with respect to field size, turn-around areas, and compatibility with existing equipment, are even more stringent for irrigated than for nonirrigated areas. Refer to the nonirrigated section for additional discussion (NIA-11).

Improved Water Management (IA-12)--

The predominant form of surface irrigation in the western states is furrow irrigation. Historically, most irrigating was done on the basis of fixed rotation or visual crop symptoms rather than by scheduling the irrigation to meet predicted crop demands. Where an ample supply of water existed, many of these systems operated inefficiently. Often farmers have used a relatively small stream size in order to minimize visual runoff losses. As a consequence, they induced relatively large deep percolation losses because of nonuniform water application between head and tail portions of the field.

Uniformity of furrow irrigation is maximized when the "intake opportunity time" at both ends of the field are equal. Since water is conveyed from the head end to the tail end of the field, equal intake opportunity times along the furrow are not possible. The least watered area of the field is at the bottom end, so under existing management practices, the highest attainable irrigation efficiency is achieved when the root zone in this area is just refilled.

There are two "operational" wastes which occur under furrow irrigation. The first is the water percolating below the root zone; the second is the runoff from the lower end of the field. Efforts to reduce one often increase the other. Salinity control practices which reduce deep percolation, for example, will often cause high runoff to control one type of waste without excessively increasing the other may thus require some system modification.

Call Period or On-Demand Watering Ordering (IA-12)--

To optimize crop production while minimizing water quality impact, water allocation systems must provide sufficient, but not excessive, quantities of water to farmers upon request. Insufficient amounts reduce crop production, whereas excessive amounts can increase the water quality impact of return flows. The use of a call period, a minimum length of time prior to the next irrigation during which an irrigator could place an order for water with the canal operator, would improve water deliveries. Call periods allow for better scheduling by canal operators and encourage farmers to carefully plan their irrigations.

Although on-demand scheduling provides maximum flexibility of irrigation scheduling, it encourages less planning of irrigation operations by the grower. Such scheduling is desirable when center-pivot irrigation systems are established on irrigated lands designed for surface water deliveries. Otherwise, unused irrigation water can rapidly fill storage ponds and lead to substantial erosion on its way to natural or artificial drainage ways. This is particularly a problem because center pivot systems are normally designed to begin and complete revolutions at a different time each day (to avoid systematic crop water stress patterns in the field). Ditch riders, on the other hand, normally make thier rounds to increase or decrease farm unit diversions at the same time each day.

Irrigation Scheduling (IA-12b)--

Irrigation scheduling is a well established practice. Irrigation scheduling services, both public and private, generally combine meteorological data or evaporation pan information with soil moisture data to forecast irrigation requirements. Both the appropriate depth of water application and the proper timing of the irrigations are estimated.

Most commercial services also combine pesticide and fertilizer recommendations with the irrigation schedule. Increases in farm productivity and reduced pollutant problems are benefits of the service. In addition, irrigation forcasts allow the farmer to more effectively schedule farm duties.

Conveyance Channel Maintenance (IA-13)--

Improper canal maintenance causes wide fluctuations in water levels along the canal length which make it more difficult for farmers to apply water uniformly. Uniformity of application, as discussed previously, is a key factor in maximizing the benefits of applied water and minimizing water quality impacts. Canals must be kept free of silt deposits and protected from scour to permit free movement of irrigation flows. Aquatic vegetation in and along canals needs to be controlled periodically to maintain canal capacity, reduce unnecessary evapotranspiration losses, and prevent clogging at control structures. Canal banks, damaged by burrowing rodents or breaks, must be repaired to prevent excess erosion or seepage losses. Structures employed in canal systems must also be properly maintained against leakage, settling or general wear. Improper canal maintenance causes wide fluctuations in water levels along the canal length which make it more difficult for farmers to apply water uniformly.

Improved Management of System Storage (IA-14)--

Measures to improve system storage assist water managers in timing irrigations to decrease over-application. **Although system water storage provides operational flexibility and more efficient water use, it should be minimized to keep seepage and evaporation losses as small as possible.** If water storage is needed throughout a river basin, water should be stored only as high in the basin as practicable, so that water surface area evaporation losses are reduced and flexibility in diversions is increased.

Improved Management of Return Flows (IA-15)--

Seasonally, many irrigation systems have a larger volume of water available than is necessary to adequately supply crop demands. Instead of properly cutting back diversions at the river or reservoir in such cases, **it is common to operate canals at capacity at all times with unneeded water spilled into wasteways.** High flows between irrigations are especially true for canals that are relatively long and have slow response times. This custom produces an unnecesary soil erosion from unlined canal ways, and high pollutant concentrations.

Land Retirement (IA-16)--

A large part of irrigated pasture provides only small returns to producers. Most of this irrigated pasture land is unsuitable for more intensive crop production. Retirement of this irrigated land from production would appreciably improve water quality at a relatively small cost.

Vegetative Controls

Crop Rotations (IA-17)--

Use of crop rotations permits the use of deep-rooted crops to "scavenge" residual soil nitrogen remaining from shallow-rooted crops of high nutrient and water requirements. **Rotations also provide greater economic flexibility when adopting management systems, permit control of many insects and plant pathogens, and permit periodic establishment of soil conditioning or salt-tolerant crops in particular problems areas.** Refer to the nonirrigated section for additional discussion (NIA-12 and 13).

Winter Cover Crops (IA-18)--

Although not traditionally regarded as applicable to irrigated agriculture, this practice is now used with increasing frequency in sandy areas where winter and spring wind erosion is a serious problem for unprotected soil, and during early-eseason furrow irrigation when excessive erosion may occur. The cover crop may also "scavenge" nitrate which leached below the root zone of shallow-rooted crops the previous season.

Field Borders (IA-19)--

Field borders or filter strips are a common sediment-control measure in furrow-irrigated settings. This practice is not well-suited to erosive crops such as potatoes and close-grown crops such as alfalfa. With erosive crops, the filter strip rapidly becomes covered and ineffective, and with close-grown crops, the fine sediment which may be eroded is not filtered by the grassed strips. Double and triple-planted wheat has been used effectively as a filter strip material for furrow-irrigated fields. Refer to the nonirrigated section for additional discussion (NIA-12 and 13).

Structural Controls

Diversions and Interceptor Drains (IA-20)--

Subsurface diversions by interceptor drains may be used to intercept groundwater bearing substantial loads of salinity or nitrates. See non-irrigated section for a discussion of these control practices (NIA-20).

Land Leveling (IA-21)--

Land leveling is commonly used to prepare land for furrow or border irrigation. **Irrigation uniformity can be increased when land is at a constant grade.** This practice, however, can have negative impacts on the soil. Calcium carbonate accumulations, for example may exist at relatively shallow depths in the native soil, and distribution throughout the soil would reduce its quality.

Retention Ponds (IA-22)--

This control practice is common throughout the irrigated west. **It appears to be one of the most cost-effective practices for sediment control in furrow-irrigated areas.** Refer to the nonirrigated section for additional discussion (NIA-23).

Seepage Control (IA-23)--

Many unlined canals, ditches, laterals, and watercourses traverse long distances between the point of diversion and the farm. Where soils are well structured and permeable, seepage losses may be considerable. **Traditionally, canals with high seepage loss have been lined with a variety of alternative materials, including concrete, asphalt, bentonite, compacted earth, and plastic.** The economic justification of such lining has been based on the value of water saved. Converting to a closed conduit of concrete, asbestos-cement or plastic is a relatively costly yet an effective alternative that offers advantages of less friction, reduced evaporation, better maintenance of pressure due to gravity, and improved aesthetics. **The salt contribution from conveyance seepage often exceeds that leached from the irrigated land,** thus conveyance linings can frequently decrease salt loading significantly. Seepage water does pass through recently fertilized soil, so its nitrate content is generally lower than that of percolation losses from cropland.

Flow Measurement and Control (IA-24)--

Poor water management leads to application inefficiencies, which reduce yields and/or impair water quality. Under-application may lead to localized salinity problems, whileover-application may cause excessive runoff of sediments and associated pollutants as well as leaching of salts and nitrates. **The purpose of flow measurement and control in irrigation systems is to ensure an adequate application of water to croplands, while preventing unnecessary and wasteful diversion which may result in poorer water quality.**

In order to control the flow of water in canals or ditches, structures referred to as checks and drops are used. These structures control the slope and elevation of water surfaces. They are also critical in dividing water, as well as distributing water to each field. Other control structures include culverts and field inlet devices.

Optimizing Furrow Advance Rate (IA-25)--

The flow in surface furrows should be such that the advance time for the field is about 25% of the total set time, assuming a uniform slope. If this practice is implemented and strictly adhered to, deep percolation losses may be greatly reduced. Flow rate and volume can be adjusted to furrow slope and length to satisfy these criteria.

Cutback Irrigation (IA-25a)--

With this method, the head ditch or delivery pipe is adjusted so that a large "wetting" furrow stream is introduced to quickly advance the flow to the end of the furrow. The flow is then "cutback" to a "soaking" flow rate in order to complete the irrigation. **Benefits of this practice include increased uniformity of application, reductions in tailwater runoff, and low labor costs.** This method is applicable, however, only if sufficient cross slope is available.

Gated Pipe System (IA-25b)--

Gated pipe irrigation systems combine features of both the improved furrow and the cutback systems. The gated pipe system can in turn be controlled by a time clock or a master control panel. When coupled with on-demand water availability, irrigations can be scheduled according to crop needs. Length of set can be automatically controlled, so that uniform set times are no longer required. Stream size can be automatically cut back when the stream reaches the end of the field.

Multi-set Irrigation System (IA-25c)--

The automatic multi-set irrigation system combines features of the improved furrow system with a shorter length of run, by having several lateral supply pipes across each irrigated field. Irrigations can be started automatically and can be scheduled to meet crop needs. **Length of set can be automatically controlled, and the shorter length of run reduces the period of furrow advance. This in turn increases uniformity and decreases deep percolation. In addition, a shorter length of run allows for the use of a smaller stream size, which reduces runoff.**

Subsurface Drainage (IA-26)--

Any expansive area upslope from existing irrigated lands may cause waterlogging of downslope areas. If the underlying strata are sufficiently permeable, tile drainage is an effective means of lowering the water table and facilitating salt movement from the root zone. In addition, **tile drainage allows for the collection of surface return flows into a master drainage system for ease of control and/or treatment.**

Pump Drainage (IA-27)--

Pumps have also been used effectively for lowering the water table in many areas. If the water is not too saline, it can be reused directly, or after mixing with surface water supplies by discharging the flow back into laterals. For good quality groundwater supplies, pumping serves the dual purpose of alleviating waterlogging and providing additional irrigation water. With poor quality supplies, however, disposal of the pumped water may constitute a major problem.

Level Furrows or Diked Basins (IA-28)--

For flat landscapes and relatively deep soils, fields can be levelled and diked at one end to prevent surface runoff, and to improve uniformity of application. With this system, irrigation efficiencies greater than 90% have been achieved in some instances.

Sprinkler Irrigation (IA-29)--

Sprinkler irrigation, if properly designed, installed and operated, results in both water quantity and quality benefits. **Relatively uniform water application is generally possible on various types of soils, thereby minimizing deep percolation losses. Little or no tailwater runoff results,** except when infiltration rates are exceeded on fine-textured soils. Sprinkler systems commonly used include side-roll, center-pivot, tow-line and solid-set sprinklers. The last two are frequently used in orchards and vineyards.

There are disadvantages to sprinkler systems, however: (1) poor quality irrigation water may cause salinity damage to crops and leave undesirable deposits or coloring on leaves or fruit, (2) sprinkler-irrigated crops are more susceptible to certain diseases, and (3) the high capital costs associated with the sprinkler and the fuel and/or energy costs to run the system may make sprinkler irrigation economically impractical for certain crops.

Trickle Irrigation (IA-30)--

The concept of trickle irrigation is to provide crop plants with near-optimal soil mositure by conducting water directly to individual plants through lines or emitters. In widely spaced crops (especially orchards), losses are reduced because only a small portion of the soil surface is wetted and subject to evaporation. **Little water is lost via deep percolation, since only the plant's root zone is supplied with water. The only irrigation return flow is associated with the occasional leaching necessary to prevent excessive salt buildup in the root zone.** Because of continual leaching of salts and nutrients to the periphery of the wetted area, nitrate concentrations of these return flows can be exceptionally high. There is no surface runoff, and little water is consumed by weeds with this system.

Trickle irrigation systems are easily automated, but they usually require skilled technical assistance for estimating nutrient balances and fertilizer applications. Irrigation waters should be relatively high quality. Filtration and chlorination are often required to prevent clogging of emitters. Emitters are economically practical for widely spaced crops if the average distance between emitters is more than 3 meters. The capital cost of trickle irrigation is relatively high. Trickle irrigation systems are particularly adaptable to perennial high valued crops, such as orchards and vineyards.

Collection, Treatment and Disposal of Return Flows (IA-31)--

In many cases, subsurface and surface return flows from irrigated lands may be so brackish that no further use of the water is possible. Such flows can be collected and either disposed of or treated before they enter receiving waters. **Reverse osmosis and electrodialysis are two desalination processes that can be used to reduce salt concentrations in irrigation return** flows. **Major disposal alternatives include deep well injection and evaporation ponds.** In general, the cost of collection, desalination and brine disposal for salinity control exceeds the costs required to achieve the same level of salt reduction through improved irrigation efficiencies.

Institutional Controls

Tax on Farm Inputs --

Charging a farm operator in excess of the market price for fertilizer, pesticide, or water would theoretically decrease the amount used by encouraging more efficient use.

Discharge Regulation --

Since the amount of water, nutrients, and sediment leaving a farm in surface flow can be monitored, it is possible to estimate pollutant discharges. Based on these estimates, **loading limits can be established for farms or irrigation districts.**

Regulating Farm Inputs --

Nutrient and water requirements for maximizing crop yields can be estimated based on agronomic research and experience of local growers. **Irrigation and fertilizer applications can be regulated to conform with agronomically sound recommendations.**

SECTION 4

METHODS FOR THE EVALUATION AND SELECTION OF AGRICULTURAL NONPOINT SOURCE CONTROLS

The selection of agricultural nonpoint source (NPS) controls involves a series of steps and calculations. This section presents methods by which nonpoint source controls can be evaluated. Application of the methodology to two case study watersheds is described in Section 5.

The selection process presented in this section **involves an evaluation of two basic factors: 1) NPS practice effectiveness in controlling a particular pollutant pathway, and 2) farm costs associated with the practices.** The steps outlined in this section generally apply to all agricultural systems. The seven steps of the BMP selection process are shown in Figure 5.

STEP 1: DESCRIPTION OF WATERSHED

In order to develop and evaluate NPS control strategies, physical, hydrologic, and crop/livestock information will have to be compiled. Physical data includes maps of land use, topography and soils for the study area. Available hydrologic data, including rainfall, runoff, and groundwater records, should be located. The types and extent of agricultural enterprises in the area should also be noted. The technical appendices document specific data needs and collection methods.

STEP 2: PROBLEM IDENTIFICATION

The identification of impaired water uses and associated problem pollutants, determination of the relative contribution from agricultural nonpoint sources, and calculation of the extent to which these pollutants should be controlled are of primary importance. This information establishes the basis for the implementation of control practices. **Although methods for determining the existence of a pollution problem and the necessary level of control are beyond the scope of this manual, the general approach is briefly described below.**[3]

Impaired water use provides the first indication of problem pollutants and their sources. Cause and effect relationship must then be established

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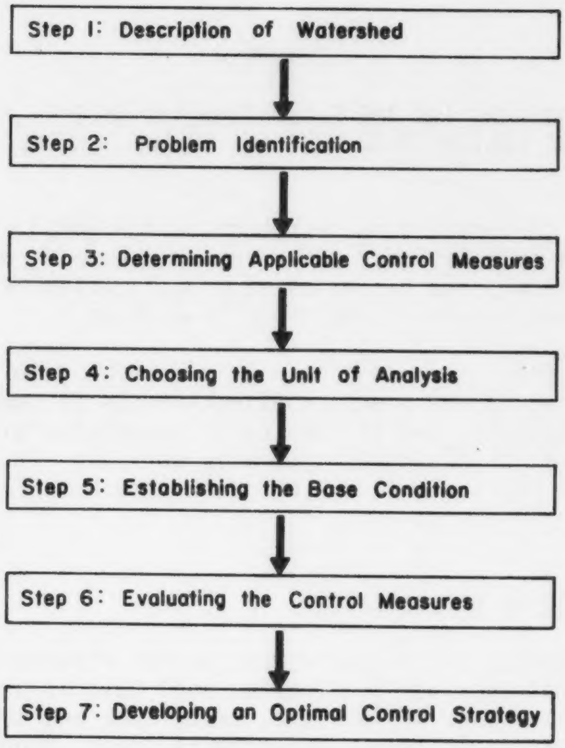
[3] The reader is referred to Chapra (1980), Thomann and Segra (1980), Di Toro (1979), Wineman et al. (1979), Heaney and Ammon (1979).

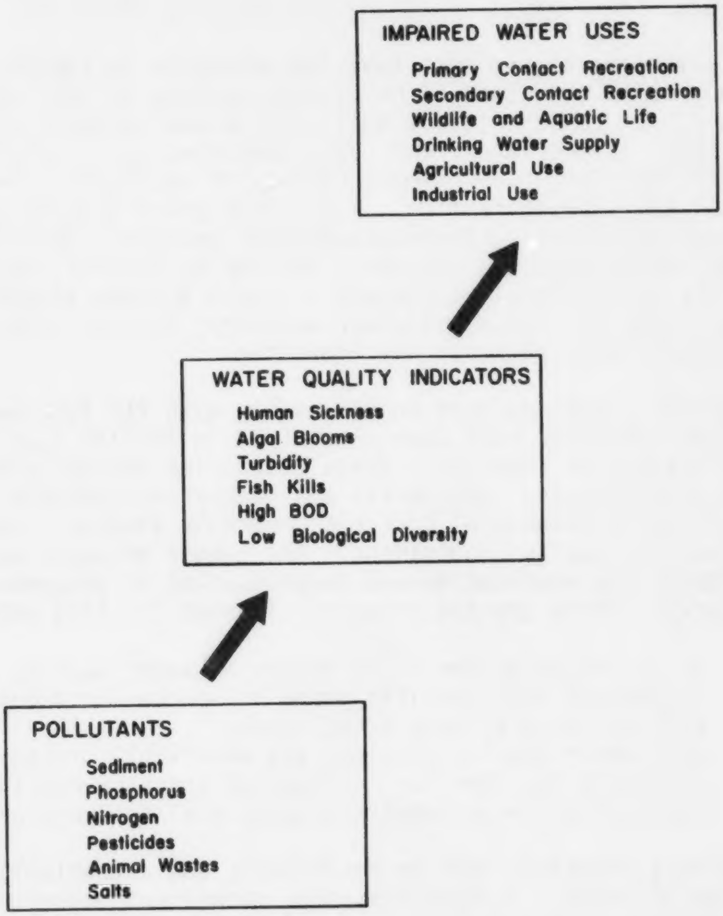
Figure 5. Steps of the BMP evaluation process.


Step 1: Description of Watershed
Step 2: Problem Identification
Step 3: Determining Applicable Control Measures
Step 4: Choosing the Unit of Analysis
Step 5: Establishing the Base Condition
Step 6: Evaluating the Control Measures
Step 7: Developing an Optimal Control Strategy

between water uses, water quality indicators, and contributing pollutants (Figure 6). Water quality monitoring data is in all cases required. The extent of monitoring will vary considerably with the availability of project resources. Proper design of limited grab sampling programs can yield valuable data.

The relative contribution of point and nonpoint sources to pollutant loads above background or natural levels must be estimated. If the NPS load is small compared to the point source load, NPS control may have little impact on water quality. If, however, the NPS load is significant, then the relative contribution of various nonpoint sources must be estimated. In evaluating loads from agriculture, a 'manageable' agricultural load must first be determined; a manageable load is defined here as the component of total agricultural load. If the manageable agricultural load is small relative to other nonpoint sources relative to other nonpoint sources, controlling agricultural NPS pollutants may not

Figure 6. Water uses, water quality indicators, and pollutants involved in nonpoint pollution.



improve water quality significantly. Figure 7 shows the steps involved in determining the controls necessary to meet water quality goals.

Since the determination of a control strategy is ultimately based upon an analysis of cost-effectiveness, in the early stages of planning rudimentary cost comparisons of controlling the various possible pollutant sources should be developed. These comparisons will help determine which sources should be treated first.

STEP 3: DETERMINING APPLICABLE CONTROL MEASURES

The process by which alternatives can be selected and evaluated, once specific water quality problems have been identified, can be generalized for all problem areas. Four basic screening criteria are involved:

1. **The practices chosen must have the potential to control the pathway of the problem pollutant** . The primary pathway of nutrients strongly adsorbed to soil and sediment is the soil erosion and sedimentation process, whereas the pathway of moderately and weakly adsorbed pollutants is soil erosion and overland flow. The primary pathway of nonadsorbed pollutants is deep percolation and subsurface flow. A practice which acts to control one or more pollutant pathways is termed a candidate measure. Candidate measures can be ranked according to their ability to control the primary pathway(s) of the pollutant(s) of concern. Figure 8 shows elements involved in agricultural nonpoint source pollutant delivery; factors affecting the three major pollutant pathways are indicated.

2. **Candidate practices must be compatible with the farm management system.** Candidate measures have been classified in Section 3 as managerial, vegetative, or structural controls. These categories reflect differences in the permanence of practices; managerial and vegetative controls must be renewed annually while structural controls generally involve a much longer time horizon and some capital investment. **The nature of water quality management suggests the application and re-evaluation of progressively more permanent measures.** There are two principal reasons for this approach:

   (a) It is likely in the early stages of water quality management that specific nonpoint source contributions will not be precisely established.
   (b) Many water quality problems are reversible processes providing the time for incremental practice application and evaluation of resulting water quality improvements.

3. **Candidate practices must be technically and economically feasible in the area of study.** In most instances management controls will be appropriate. **Certain structural and vegetative measures may not be suitable because of topography, soil characteristics, climate, equipment limitations, or marketing factors** (see Table 4). For example, contour farming (NIA-11) is a widely used and effective soil erosion measure, but excessive slope lengths limit its effectiveness. Contouring, in addition, is difficult to implement on complex slopes or with certain large modern farm machinery. If

Figure 7. Steps involved in determining the levels and types of controls necessary to meet water quality goals.

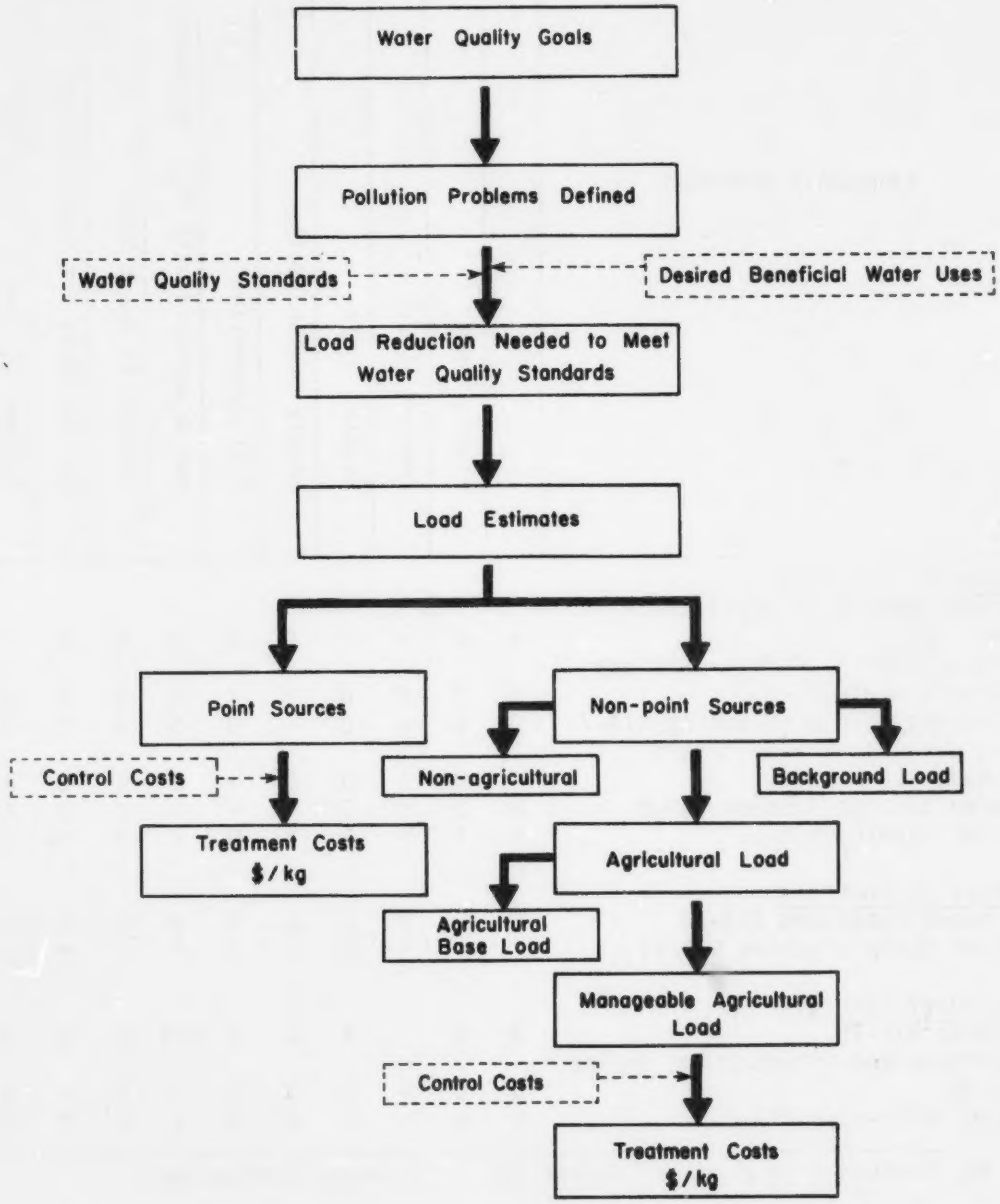
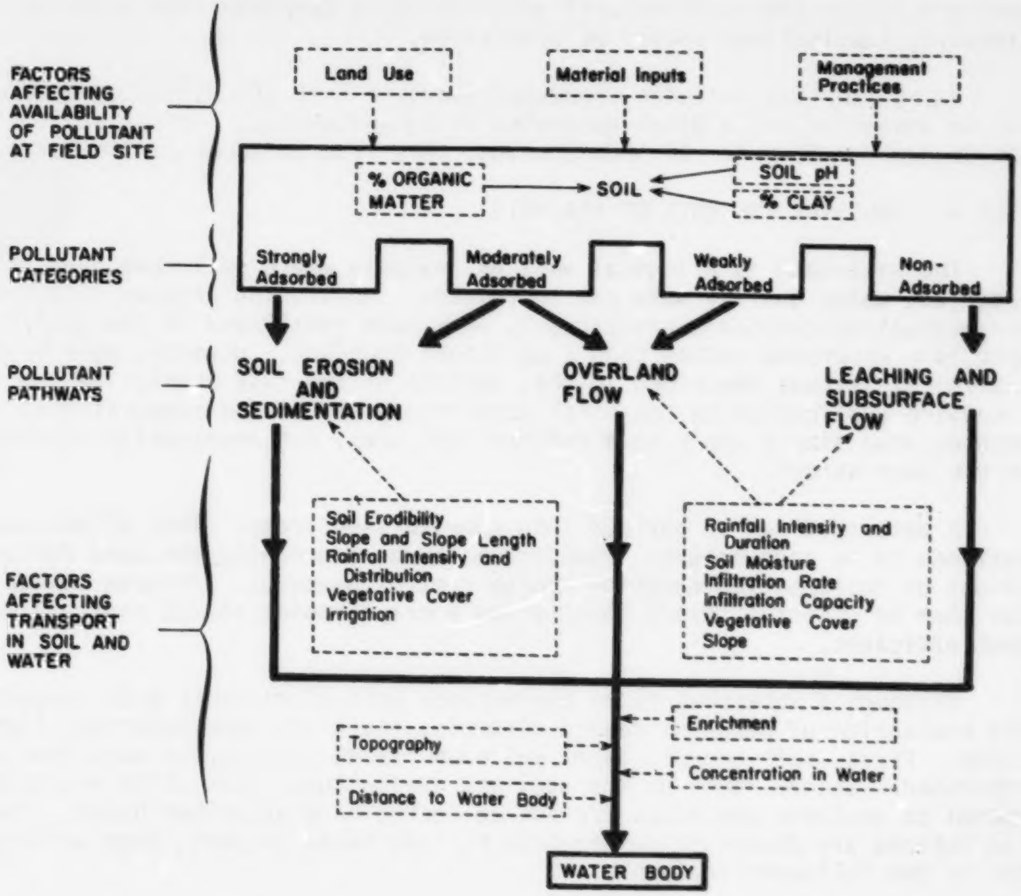


TABLE 4. DEGREE TO WHICH VARIOUS PHYSICAL VARIABLES LIMIT THE USE OF CANDIDATE MEASURES

CANDIDATE MEASURES	Soil and Topography						Equipment			
	Slope	Slope Length	Complex Slopes	Shallow Soils	Poorly Drained Soils	Soil Compaction	Not Compatible with Wide Equipment	Results in Point Rows	Not Suitable For Small Fields	Reduces Equipment Efficiency or Requires New Equipment
Managerial Controls										
Improved method of application NIA-3	+	0	+	0	0	0	0	0	0	*
Improved timing of field tillage operations NIA-4	0	0	0	0	*	*	0	0	0	0
Optimizing time of planting NIA-7	0	0	0	0	+	0	0	0	0	0
Using mechanical weed control methods NIA-8	+	0	*	0	0	+	0	0	0	+
Reduced tillage systems NIA-9	0	0	0	0	*	+	0	0	0	*
Contour farming NIA-11	*	*	*	0	*	0	+	*	*	0
Vegetative Controls										
Sod based rotations NIA-13	0	0	0	0	0	0	0	0	0	+
Contour strip cropping NIA-15	*	*	*	0	0	0	*	*	*	+
Structural Controls										
Terraces NIA-19	0	0	*	*	0	0	*/+	0	+	0
Diversions and interception drains NIA-20	0	0	+	0	0	0	+	0	+	0
Grassed Waterways NIA-21	0	0	+	0	0	0	+	0	0	0

0 = Not limited; + = Minor limitation; * = Major limitation

Figure 8. Elements of the agricultural NPS pollutant delivery process.



poorly drained fields are contoured, surface drainage may be even further decreased. Certain practices, such as terraces (NIA-19) may not be well-suited for modern farm equipment or areas where shallow topsoil overlays less permeable subsoils. Although terrace design may be modified to overcome these limitations in some cases, additional costs and risks should be noted.

4. **Candidate measures must be screened according to their fundamental socio-economic feasibility.** It should be emphasized that the effectiveness of most NPS controls and the economic impact of practices are strongly influenced by crop rotations. The fact that certain crop rotations exist in a

particular area often reflect both long term and short term market adjustments by farm operators. Changing rotations or introducing new crops as a control measure such that farm crop production is decreased should, in most cases, be discouraged. Where these changes are technically necessary or more profitable than a structural alternative, a comprehensive study of the marketing implications should be undertaken.

Using the four criteria discussed above, a list of candidate measures can be assembled for a given watershed or sub-watershed. This list is the end product of Step 4. In Step 5 below, this list is screened further.

STEP 4: CHOOSING THE UNIT OF ANALYSIS

The watershed is a logical unit of analysis where pollutant load estimates and water quality data can be related. Monitoring problem pollutants and evaluating candidate practices is very much simplified if the analytical unit is a watershed rather than a political boundary. However, none of the analytical methods described in this section or the case studies in Section 5 require application to the total watershed. All of the computational methods used simply apply to a defined land area, not necessarily draining to the same stream.

A watershed can be divided into subwatershed areas. This allows comparisons to be made between subwatershed areas concerning the need for and effect of implementing nonpoint source control measures. Program emphasis can then be directed toward those areas where nonpoint source controls are most efficient.

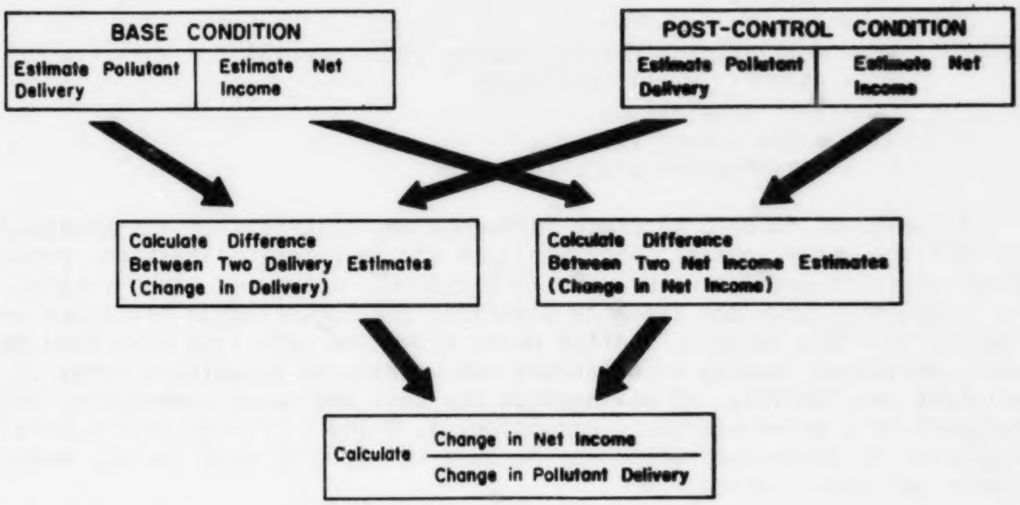
Although a watershed is an appropriate unit of analysis with respect to the evaluation of nonpoint source controls, there are some important limitations. First, soil groups, farms and even fields can overlap more than one watershed. Second, much of the soil and agricultural statistics and data needed to evaluate practices are not collected on a watershed basis. These limitations are discussed in Appendix F; they have, in part, been accounted for in the following analyses.

In evaluating NPS controls at the watershed level it is generally assumed that controls do not affect the prices paid or received by farmers. This assumption is not valid for large areas (eg., corn belt) where widely adopted NPS controls would significantly reduce the market's supply of commodities or farm inputs.

STEP 5: ESTABLISHING THE BASE CONDITION

The choice of efficient nonpoint source controls requires that the cost-effectiveness of candidate practices or sets of candidate practices be compared. For the methods presented in this manual, **cost-effectiveness is defined as the change in farm income compared to the change in delivered pollutant load caused by practice implementation** (Figure 9).

Figure 9. Steps involved in determining cost-effectiveness.


BASE CONDITION
Estimate Pollutant Delivery
Estimate Net Income
POST-CONTROL CONDITION
Estimate Pollutant Delivery
Estimate Net Income
Calculate Difference Between Two Delivery Estimates (Change in Delivery)
Calculate Difference Between Two Net Income Estimates (Change in Net Income)
Calculate
Change in Net Income
Change in Pollutant Delivery

To determine the cost-effectiveness of a particular candidate measure, the pollutant loading and farm income before and after practice implementation must be determined. The present farm management system and the associated pollutant load should serve as the basis for the comparison of alternative systems. For example, if fall plowing is the common practice in the watershed, it should be considered as one of the base management practices. Since costs and impacts of applying most BMPs will vary widely depending on the productivity, slope and drainage of soil, cost effectiveness must be determined for each important soil or for groupings of similar soils.

Calculating Pollutant Loading

To determine pollutant loading from a watershed, overland and subsurface water flows and the soil loss for each soil group in the watershed must be approximated. Conceptually, the movement of surface and subsurface water from cropland to streams can be described as follows:

$$U_t + O_t = P_t + I_t - E_t + B_t + D_t$$

Where: U_t = subsurface flow (cm) during time interval t
O_t = overland flow (cm)
P_t = precipitation (cm)
I_t = irrigation application (cm)
E_t = evapotranspiration (cm)
B_t = change in surface storage (cm)
D_t = change in subsurface storage (cm)

The amount of soil loss can be estimated using the universal soil loss equation (USLE) or some modification of USLE:

$$A\upsilon = RK(LS)CP$$

Where: $A\upsilon$ = soil erosion (kg/ha) during time interval t
R = rainfall erosivity factor
K = soil erodibility
(LS) = slope length factor
P = conservation practice factor

A number of factors strongly influence the distribution and quantity of the soil and water losses. Soil drainage and hydrologic condition, precipitation duration and intensity, soil erodibility, slope and slope length, field capacity, crop and cropping practices and conservation practices are examples of these factors. **After water flows and soil loss have been estimated, pollutant loading calculations can be made by assuming a level of pollutant availability, of mixing with the soil and water components, and of transport to a water course.** Appendices A, B and C include a more detailed discussion of techniques which can be used to estimate soil, water, and related pollutant losses.

As discussed in Section 2, pollutant availability and transport involve complex processes. For example, inorganic nitrogen (N) is made available from soil each year and the decay or mineralization of manurial organic matter of crop residues add to the pool of inorganic N. In addition, the actual concentration of inorganic N in a particular soil may change after precipitation events, as transformations take place between different forms of N and as volatilization and denitrification losses occur. A set of particular crop, soil, and climatic conditions determine plowing, planting, and emergence dates as well as fertilizer needs, crop uptake, and yield. These conditions determine fallow periods, rate of canopy development, amount of surface residue and, consequently, the availability of nutrients, pesticides, and salts for transport.

Pollutant Delivery --

Pollutant delivery to streams can be defined as the fraction of a pollutant leaving a defined area (e.g., field) which actually reaches a certain point in the stream in the time interval under consideration. In the case of sediment, the delivery ration is given as the quantity of suspended solids at the mouth of the watershed. It is a function primarily of the topographic and vegetative character of the terrain. Where opportunities for redeposition are greatest, the pollutant delivery ratios are lowest.

In applying the concept of pollutant delivery to substances being transported with overland or subsurface flows, the receiving stream must first be defined. A receiving watercourse can be defined as any channel where concentrated flow is evident, even if intermittent. This is a broader definition than merely a stream where water quality is monitored or where the quality of water has a direct impact on designated water use. Figure 10 illustrates examples of points that might be designated as receiving watercourses. Point A, at the mouth of the watershed, represents the cumulative contribution of the entire drainage area from both overland and subsurface flow. Point B designates a point where a roadside drainage ditch contributes intermittently to main stream flow. Point C is the location where overland flow from Field 1 drains into a roadside ditch. Point D represents direct field discharge, and Point E represents discharge across an intervening land surface. Overland flow leaving Field 2 near Point D, has a greater opportunity for infiltration, ponding and redeposition of suspended solids than does flow leaving Field 3 near Point E.

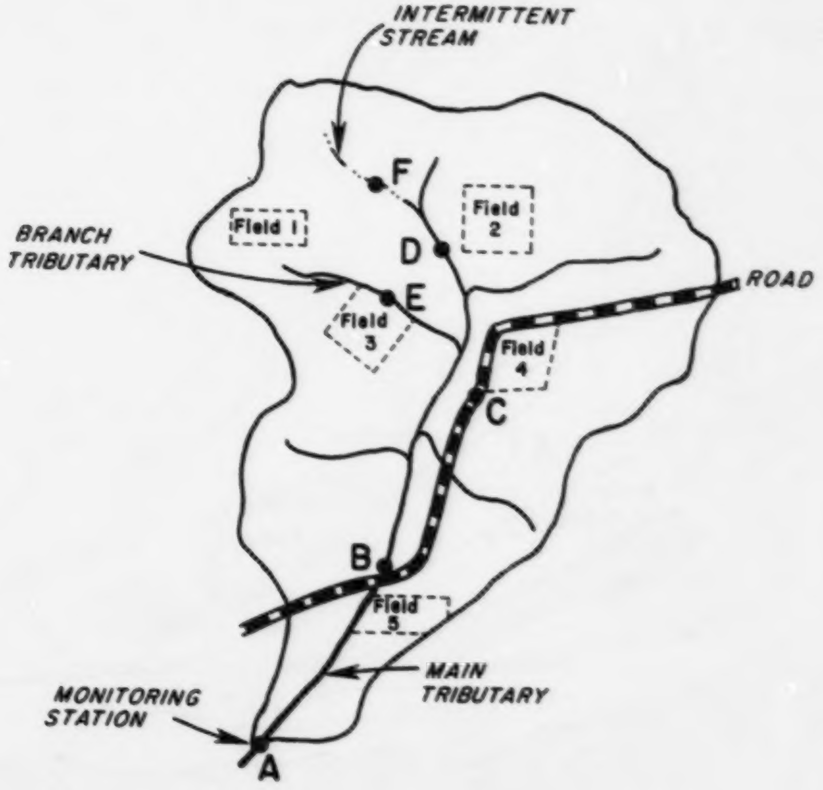


Figure 10. Examples of alternative points for the designation of a receiving water course.

In the case of subsurface flow, the definition of a receiving stream or watercourse becomes more ambiguous. Although much of the water infiltrating soil may eventually reappear as surface flow, the pathway and time frame for this process can vary greatly. Infiltrating water can reappear as interflow (Pathway A of Figure 11) or can percolate to the underground water table and flow to a stream (Pathway B). Some subsurface flow may percolate to aquifers, as Pathway C in Figure 11, but only reach a water course after considerable time. **The final form and quantity of highly soluble, conservative substances like chlorides are not significantly affected by the particular pathway taken. For substances that are either weakly retained by the soil or that degrade over time, however, the length and transit time of different pathways may affect actual pollutant delivery markedly.**

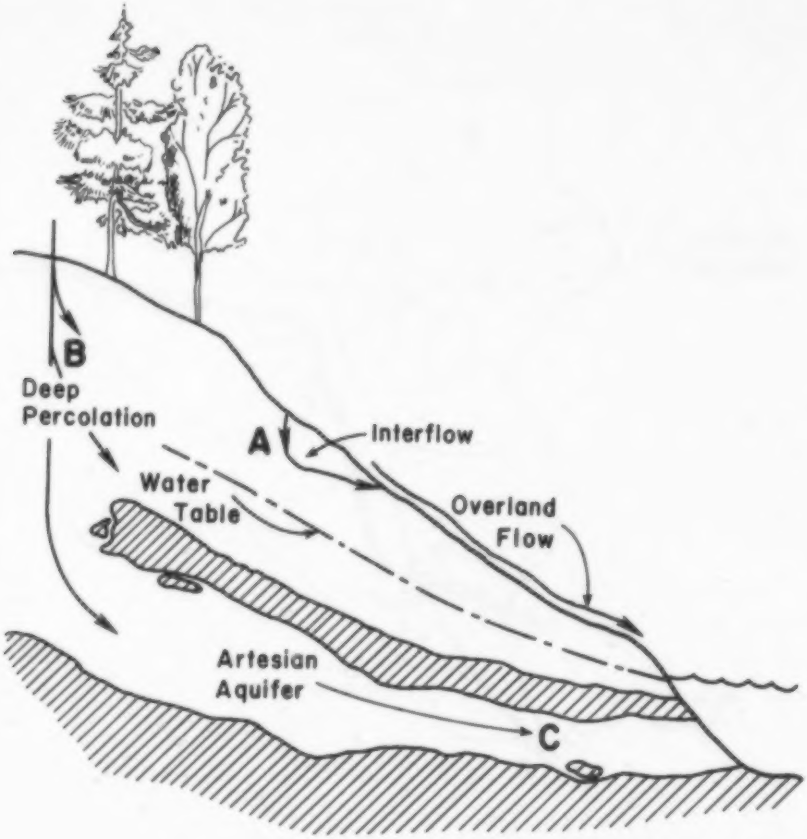


Figure 11. Pathways of subsurface flow.

Estimating the Cost of Practices

Perspective of Cost Estimates --

Estimates of the cost of nonpoint source pollution controls differ according to the perspective taken. **Control costs should include installation, operation and maintenance expenditures. From the farm operator's perspective, control costs should also include reductions in farm income resulting from farm investment in water pollution controls. From society's viewpoint, increased prices of agricultural products resulting from nonpoint source controls, as well as costs of administering programs by public agencies and changes in tax revenues, represent costs of improving water quality.** In all cases there are opportunity costs associated with alternative investment options. For example, water quality may be improved more per unit of expenditure by investing in either point or non-agricultural nonpoint source controls. Likewise, a farm operator's income may be reduced more with certain practices than with others, or the social cost of increased prices of agricultural commodities may be less desirable than the increased product prices associated with point source controls.

The level of analysis used for this manual does not incorporate national, regional or other social cost perspectives. It is assumed that prices paid to farmers for agricultural commodities and paid by farmers for goods and services do not change with implementation of nonpoint source pollution controls. All cost estimates generated with this methodology include direct installation and maintenance costs, as well as estimated changes in farm income. By estimating farm income effects, practices which are more likely to be accepted by farmers can be selected. Cost estimation is discussed in more detail in Appendix F.

Base Income Level --

A base level of farm income must be established so that the relative cost of candidate practices can be compared. Because the implementation of nonpoint source control measures does not affect all aspects of a farm enterprise, only certain returns and expenditures must be budgeted. This technique of partial budgeting can save both time and planning resources. Appendix F describes these budgeting procedures in detail.

The fixed and variable costs of production which are most affected by practice implementation include machinery, irrigation, labor, pesticide, and fertilizer costs. These costs are quantified for the base condition for each area studied since they vary from farm to farm as management practices and machinery compliments vary. Since each crop has different management requirements, cost estimates are conveniently done on a crop basis.

The base farm management system should be set up to achieve the maximum level of net income possible given the site conditions and current technology. **The base condition generally approximates profit maximizing farm operations. Losses of pollutants are estimated for this level of farm income and farm activity in the watershed. The relative changes that occur from this base condition are then used to evaluate the cost-effectiveness of control practices.**

STEP 6: EVALUATING CANDIDATE CONTROL MEASURES

Qualitative evaluations do not enable one to compare and choose NPS control measures which are best suited for a particular farming enterprise or set of field conditions. Some quantitative estimates of the effectiveness and costs of the measures, therefore, are needed. Analytical procedures to predict sediment, nutrient and salt losses with implementation of selected control practices have been developed and are described in this manual. It is difficult, however, to quantify pesticide losses because of inherent characteristics of such chemicals. The selection of candidate measures for the control of pesticide losses has therefore been approached qualitatively. Persistence, toxicity, drift, and volatilization vary for different pesticides and for varying soil, water, and wind conditions. In many cases, the quantity, destination and toxic effects of pesticide volatilization and drift are unknown. Quantitive methods which may be used to estimate pollutant loads include the Universal Soil Loss Equation (USLE) for sediment losses, SCS Curve Number for runoff leaching losses, and simulation modelling for nutrient losses. Partial budgeting and linear programming are used to estimate net income. These methods are discussed below.

Sediment Loss From Non-Irrigated Fields

Sediment loads to a stream can be estimated by calculating gross field erosion and an appropriate sediment delivery ratio (SDR). A common method for estimating rill and inter-rill erosion is the Universal Soil Loss Equation (USLE). The USLE predicts, for a specific area, the average annual rill and inter-rill soil erosion created by rainfall and associated runoff. The land area being evaluated can consist of either a single field or a larger area. The predictive accuracy of the USLE, however, decreases for slope lengths greater than 122 meters. Details of the USLE and how it can be used to predict erosion and adsorbed pollutant losses are given in Technical Report A.

Sediment Loss from Irrigated Areas

Although irrigation practices are designed to result in greater control over water use and movement, soil erosion and sedimentation are evident on all furrow-irrigated lands. Sprinkler irrigation systems can result in localized runoff and erosion problems, such as when heavy application occurs near the periphery of center-pivot sprinkler systems of moderate to fine-textured soils. However, such runoff generally accumulates in the same field or in nearby depressions.

Applications of the USLE in irrigated areas are limited. One approach for estimating sediment loss was developed by Gossett (1975). **A base-level combination of crop, irrigation, and soil conditions is assumed, for which sediment loss has been measured. Other crop, irrigation, and soil conditions are then treated as adjustments, in the form of multipliers, to the base-level estimate.** This approach was used to predict erosion for the

Yakima case study in Section 5. Computational methods for estimating sediment loss from irrigated cropland can be found in Appendix B.

Estimation of Runoff and Leaching Losses

Runoff from non-irrigated cropland can be determined using a number of computational methods. One method is the curve number approach. Soil moisture is computed by quantifying all significant inputs and outputs of water. When a precipitation event occurs, water infilitrates into the soil until soil water capacity is exceeded. The remaining rainfall is runoff or is temporarily stored in surface depressions. **The partitioning of water between surface and subsurface flows is determined using the curve number, an index reflecting the potential for runoff as determined by soil hydrologic group, crop, soil management practices and antecedent moisture condition.** This method is described in Appendix A.

Runoff from irrigated cropland can be predicted with greater accuracy than non-irrigated cropland. Water application, evapotranspiration and surface return flow can be estimated directly. The quantity of water which percolates is usually assumed to be the residual loss. Runoff volume can be determined in a way similar to sediment loss in irrigated agriculture. That is, a **base level of runoff is assumed and multipliers are used to account for stream size, length of set, soil type and field slope.** Runoff estimates for these different conditions can be found in Appendix B.

Nutrient and Salt Losses from Non-Irrigated and Irrigated Croplands

Once soil and water movement have been calcultated, nutrient and salt loading estimates can be made. **These calculations account for the availability of different forms of nitrogen (N) and phosphorus (P) in the soil profile, equilibrium concentrations of N and P either associated with the soil or in solution, and changes in concentration during storm events.** Loading estimates are typically made by multiplying average or flow dependent concentrations by the calculated runoff or leaching volume. Detailed examples of nutrient loss estimates are made in Section 5 and further details are given in Appendices A, B and C.

Economic Evaluation of a Farm Enterprise

Farm operations are generally made up of a number of enterprises. Cropping enterprises may include the production of corn silage, corn grain or winter wheat. Livestock enterprises may include milk, beef or swine production. Each of these enterprises has a particular cost structure. That is, all crops have variable growing expenses (seed, fertilizer, equipment), whereas building use, land cost, insurance and interest are fixed for a given farm and do not vary appreciably among crops or for a particular year. A livestock enterprise will have a different set of variable and fixed costs. Bedding, breeding and veterinary charges are examples of variable costs, and manure disposal and feed storage are examples of relatively fixed expenditures for a typical livestock operation.

Implementation of nonpoint source pollutant controls changes the cost structure of farm enterprises. It may also reduce total production. Calculation of farm income changes thus involves an estimation of changes in cost structure and total production.

Changes in management and vegetative practices require little or no capital in the form of construction or equipment. Since all management practices apply only to existing operations, minimal direct costs of implementation, operation, or maintenance should be required. Establishing vegetative cover usually requires only tillage, growing, and harvesting expenditures. These expenses may be considered to be indirect costs of the practice if they are associated with sod or grain grown in rotations as part of existing crop enterprises. Structural practices, on the other hand, usually necessitate earthmoving and/or construction activities, which involve installation, operation, and maintenance costs.

Programming Method

Whether total or partial farm budgeting methods are used to estimate the cost of nonpoint source pollutant controls, the many enterprise and practice combinations can present a bewildering array of options. Computational assistance is now available through a number of standardized programming techniques. One of the most common methods used is linear programming (LP). **Linear Programming methods are particularly appropriate for comparing agricultural investment decisions, since numerous combinations of crops, tillage methods, fertilizer management and other activities may be evaluated for each field.** This technique is discussed in detail in Appendix F as well as illustrated in the examples of Section 5.

STEP 7: DEVELOPING AN OPTIMAL CONTROL STRATEGY

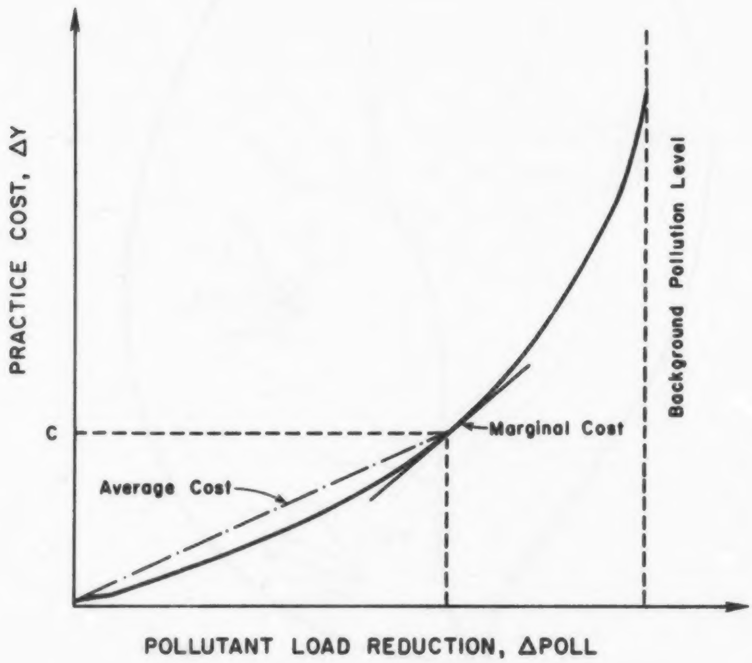
Calculating cost-effectiveness for each individual practice and combination of practices for each subwatershed unit is generally not feasible. Time and analytical resources usually limit the number of options that can be evaluated. **In order to insure the evaluation of a variety of realistic control options, sets of practices can be assembled from those screened in Step 3.** Subjective judgment concerning the compatability of certain practices to farming conditions in the study watershed must be used to reduce the number of alternatives considered. **It is important to encourage the consideration of a range of practices. The grouping of practices in Table 2 into management, vegetative and structural controls illustrates the range that might be considered.**

The cost-effectiveness evaluation of these sets of practices for different subwatersheds is the basis for developing an "optimal" NPS control strategy. There are a number of techniques which can be used to compare practice sets. Three techniques which can be used are: 1) the marginal adjustment cost method, 2) additive optimization, and 3) the efficiency frontier method. They are discussed below and are demonstrated in the case studies presented in Section 5 and in the accompanying Technical Reports.

Marginal Adjustment Cost Method

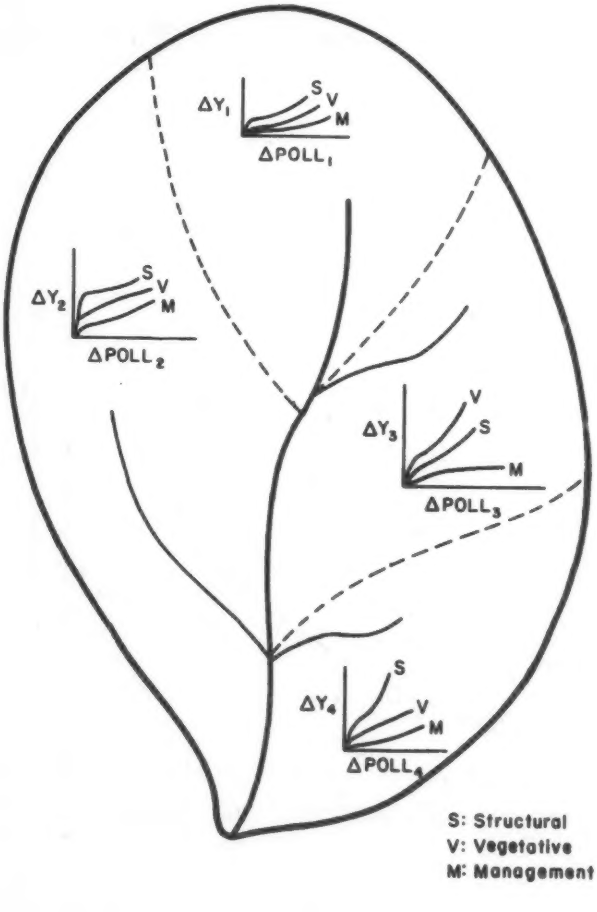
For a particular load reduction or level of pollutant load, the marginal cost to change or adjust farm activities can be estimated. The marginal cost (MC) is defined as the additional cost incurred by reducing pollutant load one more unit. For example, if the total cost of load reduction is \$500 for x units but \$510 for x + 1 units, the marginal cost at x + 1 units is \$10. Figure 12 illustrates this graphically. Point A corresponds to a pollutant load reduction of B and a change in farm income of C. The slope of the curve at Point A is the marginal cost of control. This particular curve shows a constantly increasing MC; as pollutant loading is restricted to lower and lower levels, cost increases at an increasing rate. The average unit cost (OC/OB), defined as total change in farm income divided by total change in pollutant load, thus increases as pollutant loading is reduced.

Figure 12. Marginal and average adjustment cost of pollutant load adjustments.



Marginal adjustment costs can be expected to vary for different watersheds, subwatersheds and sequences of practice treatment. Consider Figure 13. Marginal cost curves have been generated (after screening practices to determine those appropriate for the watershed) for three sets of practices: managerial (M), vegetative (V) and structural (S). In order to optimize the allocation of water pollution control funds, each unit of pollutant reduction should be achieved at least cost. This is accomplished by treating first those subwatersheds with the lowest marginal costs. In Figure 13 these would be managerial controls in subwatersheds 1 and 4.

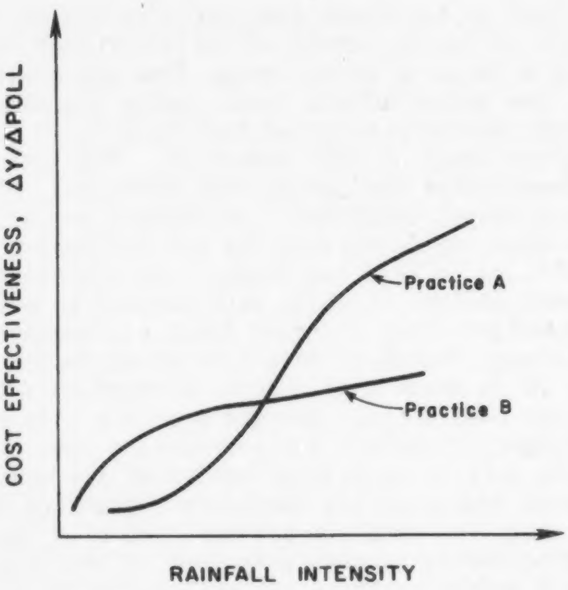
Figure 13. Marginal cost curves for sets of practices on a subwatershed basis.



The cost-effectiveness of practices also depends on the desired level of control. Certain practices have large initial implementation costs, but the unit control costs decrease at higher levels of pollutant reductions. If a relatively large pollutant load reduction is needed, these practices can be more cost-effective than practices with a low initial cost since the average cost may be lower.

The effectiveness of practices in an area may be influenced by other factors such as precipitation. For example, in Figure 14, practice "A" (contouring) may be highly effective during rainfalls of low intensity whereas practice "B" (terracing) is not as cost-effective. However, a more intense precipitation event may show practice "B" more effective than "A" (other things being equal).

Figure 14. Relationship between cost-effectiveness and rainfall intensity for two different practices.



Additive Optimization Method

The approach of determining optimal control investments is best exemplified with respect to salt control in irrigated areas. The approach is demonstrated in the Grand Valley case study of Appendix C.

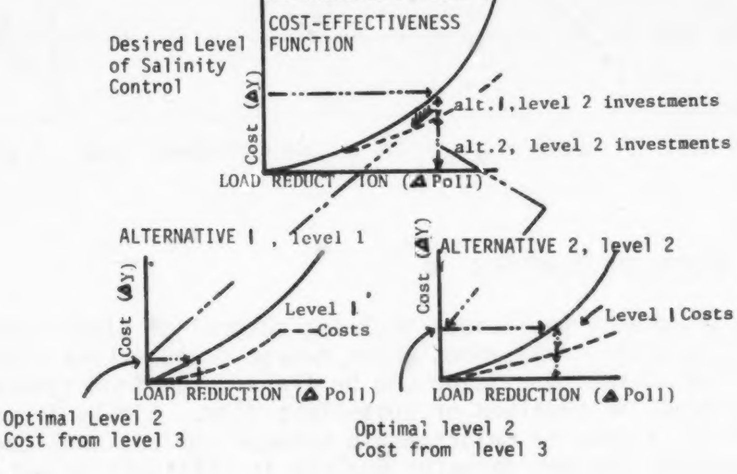
The steps involved in the additive optimization process are given in Figure 15. Alternative 1 is a particular set of practices applied to a given subwatershed area. Alternative strategy 2 is a set of practices applied to another area. Alternative 1 might involve canal levelling and lining measures while alternative 2 might involve the application of on-farm irrigation scheduling and changes in irrigation systems for a particular irrigation district in the watershed. Level 1 practices are specific practices, while level 2 and 3 are combinations of practices. The cost of implementing alternatives at various levels of effectiveness are estimated. The minimal cost of aggregate reductions in pollutant load can then be determined as a combination of level 1 practices. Subsequent load reductions for levels of practice implementation are determined in the same manner (levels 2, 3, and 4). This procedure assumes independence between practices and subwatershed units; it is assumed that the application of one practice alternative in a given area does not change the cost or effectiveness of other practice applications.

Efficiency Frontier Method

The efficiency frontier technique involves plotting the minimal cost of control associated with different levels of pollutant load reduction. **An efficiency frontier is a locus of points drawn from the evaluation of alternative NPS controls. The curve defines least costly practices at different control levels.** A rough approximation can then be made of total pathway control costs for a given level of load reduction. The Yakima Valley case study in Section 5 demonstrates the use of this technique. Figure 16 shows examples of cost-effectiveness functions. Points A-E are alternative control strategies; A might be contouring and strip cropping and B no-tillage and reduced tillage on selected soils. The efficiency frontiers can be used to evaluate each control strategy with respect to effectiveness in reducing soil loss, overland flow, nitrogen loss, and phosphorus loss simultaneously. Efficiency frontiers result in an estimated cost for each control level. Curve BE in graph 1 of Figure 16 represents the most cost-effective practices considered. Whereas practice E is relatively distant from the efficiency frontiers for controlling overland flow and nitrogen loss, practice B is relatively effective at all phases of control. Thus, for the pollutants and practices considered, practice B is the most efficient control strategy for complete pathway control. The simulation modeling and linear programming methods presented in the case study watersheds of Section 5 appear particularly well-suited to this evaluation method.

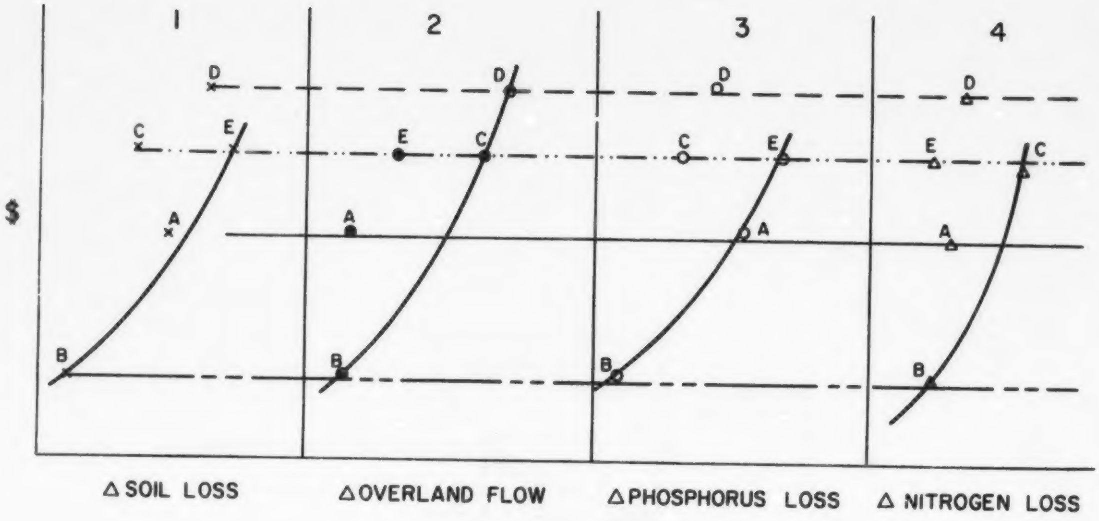
Although the preceeding sequence of data collection and evaluation methods are suitable for all water pollutants, pesticides have peculiar characteristics and therefore are treated separately. Computational methods for the estimation of pesticide losses exist, but are generally not as well-established and to a large extent remain unvalidated. The reader is referred to Davidson (1975) and Bailey (1974) for examples of pesticide evaluation methods.

Figure 15. Steps in the additive optimization process.



* LEVEL 1 COSTS ARE SPECIFIC PRACTICE COSTS

Figure 16. Efficiency frontiers showing costs of five control strategies for four different pollutants.



EVALUATION OF PESTICIDE CONTROLS

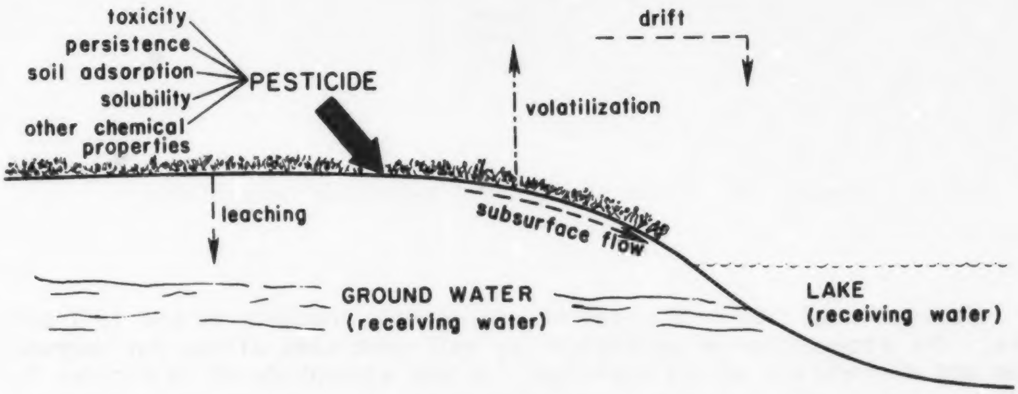
Agricultural use of pesticides includes control of plant disease, insects, mites, nematodes and weeds which damage crops. Like crop nutrients, residual amounts of pesticide can be transported from treated fields to receiving streams in overland or subsurface flow. Similarly, as in the case of nutrients, a precise relationship between agricultural use of pesticides and subsequent changes in water quality is difficult to establish. It is particularly difficult since thousands of registered pesticides are used. Also, in general, relatively small quantities are applied to cropland making detection and monitoring impractical. **Toxicity, persistence, and other chemical properties, in addition to soil adsorption, and solubility interact to influence a pesticide's impact on water quality** (Figure 17).

The influence which these properties have on pesticide availability and transport is briefly described below. Appendix E (Control of Pesticide Losses) provides additional details.

Grouping Pesticides

In order to begin considering the control of pesticide losses from cropland, it is necessary to systematically characterize the many chemical compounds which are used to control crop pests. Table 5 lists common chemicals used to control major target pests. Although general statements can be made regarding the behavior of pesticides from a specific group, the characteristics of an individual pesticide are unique and properties of each group will not necessarily apply to every pesticide in that group. In addition, some controls will be limited in their use. For these reasons, the individual properties of each specific pesticide to be controlled should be evaluated, prior to initiating a management program, in order to insure that the management practice that is selected is best suited to control the existing or potential problems.

Figure 17. Factors affecting the transport and water quality impact of a pesticide.



Persistence

One important characteristic of a pesticide is its persistence. One definition of **persistence is that period of time necessary for the complete degradation of the material into harmless products.** Since the primary mode of degradation is generally biochemical, factors which reduce biological activity decrease the rate of degradation. These factors include low soil moisture, oxygen content, temperature and organic matter content, and extreme pH (Figure 18). The relative influence of each factor depends on the specific pesticide and the site conditions.

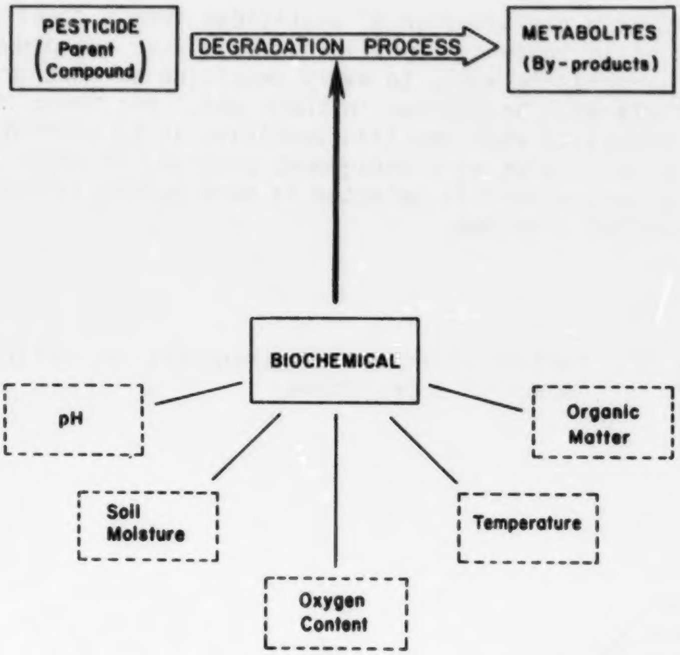


Figure 18. Factors affecting pesticide persistence.

Strongly adsorbed pesticides are relatively immobile in the soil profile. The **attenuation of pesticides by soil particles allows for degradation and dissipation of its toxicity.** Strong adsorption of pesticides to soil particles will generally keep pesticides close to the surface where they were applied. The soil surface is the area of greatest biological activity and therefore pesticide degradation rates are likely to be greater.

Organochlorines are, in general, some of the most persistent pesticides. Organophosphates, carbamates and most herbicides are more easily degraded. The triazine herbicides are degraded mainly by chemical action but can persist for substantially longer periods of time. Table 6 lists the half-lives of some common pesticides. Half-life is defined as the amount of time required for 50% of the original material to disappear. For approximately 94% of the material to degrade, it would take four times as long. Half-lives vary under different biological, chemical and physical conditions. For example, a microorganism population may adapt to the presence of a certain pesticide, thus causing an increase in the degradation rate and a decrease in the pesticide half-life. This phenomenon of adaptation can increase the need for multiple applications.

TABLE 5. SELECTED GROUPS OF INSECTICIDES, MITICIDES AND FUNGICIDES

INSECTICIDES AND MITICIDES	Chemical Compounds	Trade Name
Organochlorines	DDT	Methoxychlor
		Chlorobenzilate
	Cyclodienes	Eudosulfan
		Chlordane
		Aldrin, Dieldrin
	Polychloroterpenes	Toxaphene
Organophosphates	Phosphonodithioates	Fonofos, Terbufos
	Phosphonothioates	EPN
	Phosphorothioates	Parathion, Methyl
		Parathion, Diazinon
		Dursban, Demeton
	Phosphorodithioates	Malathion,
		Azinphosmethyl
		Dimethoate, Phorate
		Disulfoton
		Methomyl
Carbamates		Carbofuran
		Carburyl
		Aldicarb
Farmamidines		Chlorodimeform
Organotins		Cyhexatin
FUNGICIDES		
Inorganic	Coppers	Copper sulfate
Organic	Dithiocarbamates	Maneb, Ferbam
	Phthalimides	Captan, Difolatan
	Other	Benomyl, Chlorothalonil

TABLE 6. HALF-LIVES OF SOME COMMONLY USED PESTICIDES

Pesticide	Approximate Half-Life (Weeks)
Lead, arsenic, copper, mercury	500 - 1500
Dieldrin	100 - 200
Triazine herbicides	50 - 100
Benzoic acid herbicides	10 - 50
Urea herbicides	15 - 40
2,4-d; 2,4,5-t, herbicides	5 - 20
Organophosphate insecticides	1 - 10
Carbamate insecticides	1 - 5

Toxicity

Pesticides often are toxic to non-target organisms as well as target organisms. The quantitites of pesticides reaching the nontarget area, the likelihood (or risk) of exposure of organisms, and the sensitivity of the organism coming into contact with the pesticide must be considered. **The impact on specific organisms must be seen within the context of their position within a food web. Although a pesticide may be only moderately toxic to a fish species, high toxicity to organisms serving as fish foods may have an equally detrimental effect on the fish populations.** The dose-response impact of a pesticide must also be seen within the context of environmental conditions normally encountered by the test organism. Temperature extremes, nutrient levels and unusual pH may all render an individual pesticide more or less toxic to the test organism. Such synergistic toxic effects are possibly the rule rather than the exception in nature. These effects, however, are poorly understood and extremely difficult to define since the possible combinations of environmental conditions are practically infinite.

Solubility, Adsorption and Transport Characteristics

Solubility is also an important characteristic of a pesticide. **Certain pesticides are fat soluble while others are water soluble. Most organophosphates, for example, have low fat solubility. Pesticides which are fat soluble, such as some organochlorines, become concentrated in the fatty tissues of organisms, often in higher concentrations than present in the surrounding environment.** Animals which are higher in the food chain are more likely to accumulate pesticides because fat soluble compounds tend to concentrate at higher levels in a food chain. This process of biomagnification can cause severe problems of survival for a species.

Pesticides move from agricultural fields or dumping areas to streams and lakes by drift, volatilization, in the surface flow (suspended or dissolved), attached to eroding sediment, and dissolved in subsurface flow. Accidental spills or dumping of excess chemicals into surface waters also contribute substantially to pesticide levels in the water.

The quantity of pesticide lost by drift is dependent on the method of application; small liquid drop or dust applications increase losses whereas granular applications tend to decrease losses. Climatic conditions at the time of application are also important; high winds tend to disperse pesticide molecules rapidly. Volatilization depends on certain physical and chemical properties of the pesticide (i.e., vapor pressure, water solubility, adsorption coefficient), and on the moisture content and temperature of the soil. Volatile pesticides are frequently regarded as more desirable since they infiltrate soil pores more eaasily, and thus more effectively reach the target pest. However, from the viewpoint of total environmental quality, volatile pesticides may present a greater environmental risk. Volatilization increases pesticide loading to the atmosphere and the possibility of eventual redeposition to streams and lakes. In addition, the loss of pesticides by the volatilization process can be considered an economic loss since the farmer is paying for chemicals which do not end up in the target area. It has been estimated that half of the pesticides applied to field crops enter the atmosphere through vaporization from plant and soil surfaces.

Soil incorporation, cover crop, high clay and organic matter content, and deep plant penetration reduce volatilization. However, the rate of degradation of a pesticide may be decreased (the persistence increased) if the applied chemical is incorporated into the soil.

Surface and subsurface losses are determined by the adsorption and solubility properties of the pesticides, the characteristics of the site, and the timing, mode, placement, and rate of chemical application. Many of these factors can be manipulated to reduce the impact that the agricultural usage of pesticides has on water quality.

Pesticide mobility is determined in part by various factors which encourage soil adsorption. Soil adsorption tends to increase under higher soil moisture content and lower ph. In general, herbicides tend to have lower adsorption coefficients than insecticides or fungicides, although pesticide solubility varies considerably within groups.

The adsorption characteristics of the pesticide determine the mode of transport. Soluble and weakly adsorbed pesticides usually percolate downward through the soil profile. Although this is the most common pathway for these pesticides, intense rainfall, steep topography or saturated soil conditions may cause them to be lost via runoff flow. **Moderately adsorbed pesticides are primarily transported in surface flow but are also lost with eroded sediment. Very strongly adsorbed pesticides like trifluralin and toxaphene are transported primarily on eroded sediment.** Appendix E describes adsorption characteristics of a number of commonly used insecticides.

The method of application affects pesticide transport processes and thus pesticide losses. Applying a moderately adsorbed pesticide on the soil surface as opposed to below the surface increases the potential for loss. In contrast, soluble pesticides are more likely to be leached if they are incorporated into the soil surface. The timing of an application is also important; chemicals applied shortly before precipitation events have a greater potential for loss.

FACTORS INFLUENCING SUCCESSFUL IMPLEMENTATION OF NPS CONTROL PRACTICES

Social Costs and Benefits

The impetus for the implementation of measures to prevent or reduce water pollution lies ultimately with the public. It is through public input that legal measures such as effluent standards, effluent taxes, and subsidies are instituted. These measures are the result of a cost-benefit analysis, in which social costs associated with implementation and with any decreases in production, and social benefits resulting from improved water quality have been weighed. Appendix F discusses these trade-offs and describes in greater detail alternative agricultural pollution control policies.

Farm Profit Maximization

Cost effectiveness analyses have typically assumed that the farm manager is maximizing short-run profits (MSRP). He adopts a particular control practice or set of practices based upon the immediate opportunity cost (i.e., the perceived value of how the money could be used elsewhere) of abatement. **That is, the MSRP approach assumes the decision to adopt and implement various control practices is made on the basis of their short-run profitability.** At any level of abatement, other things being equal, the efficient practice, from the farmer's standpoint is that which impacts profit least.

The MSRP approach does oversimplify the producer's decision of adoption or nonadoption by relying solely upon a static concept of production efficiency. It is clear that not all farms adjust to and adopt new technology or environmental controls equivalently. Such considerations as financial structure of the farm, managerial objectives and capacity, farm size, legal organization of the farm, tax treatment, and ability to bear risk may figure prominently in the actual control practices adopted and the speed of adoption.

The fact that a producer's net worth, disposable income, time horizon and other single factors affecting decision-making are oversimplifications has led to attempts to quantify investment decisions using what have been called multi-variable methods. For example, Carter and Cocks (1975) developed a model which included both short term and long-term objectives. The seven objectives included:

1. Maximization of the present value of future consumption.
2. Maximization of the present value of future profits, where profits are withdrawn each period.
3. Maximization of the present value of future profits, where profits are reinvested each period.
4. Maximization of the discounted cash flow rate of return.
5. Maximization of the present value of future cash flow.
6. Maximization of terminal net worth.
7. Selection of the most preferred point on an efficient locus showing present consumption versus terminal net worth.

Different results were found for all seven goals leading Carter and Cocks to conclude that the choice of goals is critical in modeling farm behavior, i.e. farmer decision-making. This they found to be particularly true of a consumption net worth tradeoff goal.

Choosing the appropriate objective or criteria will influence the cost-effectiveness ranking of practices. For a single watershed, the size, financial structure, and investment options may be reasonably similar for all farms. However, when this is not the case, the variation in decision criteria should be recognized if implementation efforts are to be successful. The economic implications of choosing a particular criteria are discussed in detail in Appendix F.

Farm Characteristics

Farm investment decisions are often influenced by tax laws. These laws bias investment decisions depending on the objectives of the farm operator. Three common strategies taken by farm operators include:

1. Reduction of actual out-of-pocket costs,
2. Deferment of income taxes,
3. Conversion of ordinary income to capital gain.

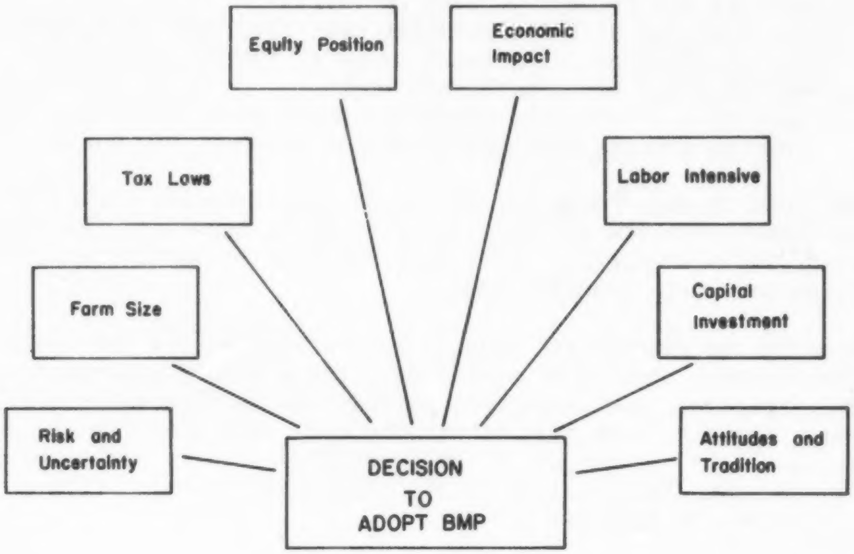
Farm size can also be an important factor influencing tax strategy and the types of NPS controls farmers are likely to invest in. **Capital intensive controls may be more appealing to large farms with tight labor constraints while labor intensive practices may be more appealing to small farms.** In addition, a weak equity position may discourage both large and small farms from investing in capital intensive controls. Figure 19 illustrates factors affecting farmer adoption of BMP's.

Risk and Uncertainty

Individual producers will exhibit widely varying perceptions of the risk associated with different control practices. Changes in technology, legal and institutional structure of farm services, yield and price variations can all influence the profitability over time.

The extent to which tax strategy, farm size, and risk preference can be incorporated into NPS control program are not clear. Appendix F discusses these factors in detail.

Figure 19. Factors affecting the adoption of a BMP.



Cost-Sharing Incentives

One common method of encouraging the implementation of NPS controls is through subsidy payments. This system has been used for some time in controlling soil erosion. These payments usually share in the cost of practice construction or installation with the farmer expected to bear the full cost of maintenance.

Cost-sharing formulas can be designed to account for some of the factors which influence the successful implementation of NPS controls. For example, cost-sharing arrangements directly affect decision criteria such as short-run profits, net worth and debt/equity ratio. In addition, factors such as farm size, tax strategy and risk/uncertainty preference can be strongly influenced by different cost-sharing formulas. Despite opportunities for using cost-sharing as a means to account for different financial preferences of farmers, little has been done in the past to incorporate these preferences into subsidy payments for practices. Generally, cost-sharing percentages have been uniform for all farms with strong bias toward capital investments. In addition, cost-sharing formulas are always based on installation and maintenance cost and not changes in income. An obvious advantage with such cost-sharing rules is the small cost of administration and practice monitoring. The principle disadvantage is that the cost-sharing program may elicit adoption patterns not commensurate with the problems to be solved.

Perhaps the major limitations to current cost-sharing criteria are that they generally exclude management practices. As demonstrated in Section V, these types of practices are often the most cost-efficient NPS agricultural controls. Therefore, limiting cost-sharing to structural controls can only lead to an inefficient water quality program.

A complete discussion of the advantages and disadvantages of alternative cost-sharing programs can be found in Appendix F.

SUMMARY

The options available to water quality planners are numerous. The control practices described in Section 3 are general categories; many variations are possible. Cost-effectiveness, suitability, and likelihood of practice acceptance are extremely important considerations in control strategy selection. The nature of water quality mangement and the limitations of data availability suggest an incremental program where practices are implemented, their effects are monitored, and then practices are refined over time. This approach is consistent with water quality goals for a number of reasons, two of which are:

1. Many water quality problems are reversible processes.
2. The complex interaction of physical and biological processes in the transport of pollutants in space and time limit our knowledge of the cause-effect relationship between practice implementation and changes in water quality.

The steps outlined in this section are a logical progression of practice screening, evaluation, and selection for a particular watershed. Many of these steps will require field work or contact with water quality managers who have access to estimates of loading concentrations and soil,topographic, and farm data. In addition, the analytical techniques, simulation modeling, and linear programming described later in this manual may require assistance from specialists. This forced interdependence between groups working to improve water quality underscores the comprehensive and complex nature of the task.

SECTION 5

EXAMPLES OF THE AGRICULTURAL NPS SELECTION PROCESS

PURPOSE OF CASE STUDIES

This section demonstrates the methodology presented in Section 4. The areas selected are from both non-irrigated and irrigated agricultural regions. Entire watersheds, sub-watershed areas and farms were modelled. In each case combinations of control practices were evaluated with respect to total pollutant load reduction and associated control costs.

Different control strategies were developed for each case. Although the techniques used to optimize levels of pollutant control and select treatment areas differed somewhat for each case study, the objective of the practice evaluations was to develop cost-effectiveness curves, as outlined in Section 4.

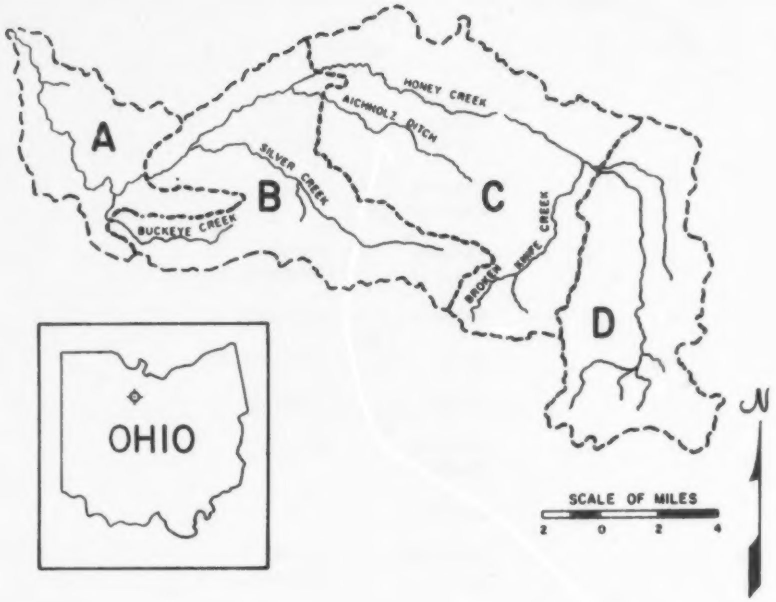
CASE STUDY I: HONEYCREEK, OHIO

Description of Watershed (Step 1)

The Honeycreek Watershed is within the Sandusky River Basin, located in north central Ohio (Figure 20). The watershed drains into Lake Erie. Considerable interest has been expressed in the watershed because of the deterioration of water quality in Lake Erie over the past few decades.

The Honeycreek watershed comprises 47,144 hectares of which over 80% are cropped. Because of this intensive agricultural use and due to its soils, Honeycreek can be considered representative of the glaciated, once forested areas of the cornbelt. Honeycreek soils are generally of fine texture with somewhat poor natural drainage on slopes of less than 3% (see Table 7). The distinctive soils and topography of the watershed are a result of glacial activity, and include areas of glacial drift, outwash, ground and end moraines, in addition to lacustrine sediments, flood plain alluvium and organic sediments. As shown in Figure 20, the watershed can be subdivided into four sub-watershed areas (A, B, C, D) based primarily on these physiographic characteristics. Subwatershed A is composed primarily of glacial drift and dissected ground moraine while the soils in B are derived from ground moraine (dissected and undissected) with glacial outwash terraces. Much of the soils in subwatershed C are ground moraine (undissected) and flood plain alluvium. Subwatershed D is primarily ground moraine (dissected) and end moraine. The watershed has been subdivided into 18 distinctive sub-areas. Table 8 lists land use and physical characteristics for each of the four main subwatersheds (A-D).

Figure 20. Honey Creek watershed.



Problem Identification (Step 2)

Agricultural land uses in Honeycreek and other watersheds draining into Lake Erie contribute organic matter, nutrients and sediment. The water quality problem most often cited in Lake Erie is the excessive growth of algae which has been attributed primarily to phosphorus loading. The annual production of algae in Lake Erie has increased twenty-fold in sixty years (Honeycreek Report, 1979). Algae growth can interfere with recreational uses of the water when it occurs near shore areas and can deplete dissolved oxygen supplies. In addition to these nutrient enrichment problems, sedimentation of navigable channels in the lake results in significant public expenditures for dredging.

Although there has been considerable study of the water quality of Lake Erie, the precise relationship between nutrient enrichment of the lake and agricultural runoff and sedimentation has not been determined. Thus specific target load reductions from watersheds including Honeycreek have not been established. For this case study analysis, a wide range of pollutant load reductions are evaluated.

TABLE 7. SOIL AND TILLAGE GROUP DESIGNATION OF HONEY CREEK SOILS

Soil Group	Soils in Group		Tillage Group
1	Bono Lorain Luray	Marengo Toledo Wallkill	4
2	Chagrin Papakating	Shoals	5
3	Lenawee Millsdale	Pewamo Pewamo-Urban	4
4	Belmore	Gallman	1
5	Haney	Hennepin-Ale.	1
6	Digby	Haskins	2
7	Belmore- Morley	Milton	1
8	Condit		3
9	Cardington Glynwood	Morley Ritchey	1
10	Bennington Blount	Tiro	2

Source: Becker and Forster (1978).

* Tillage Group 1 -- naturally well-drained soils where yield is expected to be equal to or greater than conventional moldboard plowing.

Tillage Group 2 -- response equal to or greater than conventional when surface or subsurface drained.

Tillage Group 3 -- poor internal drainage is not improved by artificial drainage measures so significant yield decreases are expected with reduced tillage systems.

Tillage Group 4 -- these soils may yield less with no-till practices even when surface or subsurface drained. Unlike group two these soils have a high organic matter content which will decrease the yield variation between extremely wet & dry years as compared to the expected yield variation using a conventional plowing system.

Tillage Group 5 -- includes organic soils, recent alluvium strip mined land and certain fine textured soils. Experience with changes in tillage practice has not been sufficiently documented to determine the general response by these soils to no-tillage.

TABLE 8. SOIL AND LAND USE CHARACTERISTICS, HONEYCREEK WATERSHED

	SUBWATERSHED							
	A		B		C		D	
	HA*	(%)**	HA*	(%)**	HA*	(%)**	HA*	(%)**
Land Use								
Row Crops	2964	45.9	6044	51.7	9668	52.1	4880	46.8
Field Crops	2080	32.2	3556	30.4	5420	29.2	3516	33.7
Other Agr.	124	7.9	52	.5	124	.7	72	.7
Forested	864	13.4	1372	11.6	1992	10.7	852	8.2
Other	428	6.6	676	5.8	1352	7.3	1104	10.6
	6460	100.0	11700	100.0	18556	100.0	10424	100.0
Slope Categories								
0-2%	4336	67.1	8512	72.7	15360	82.8	8236	79.1
2.1-4%	1104	17.1	2100	18.0	2448	13.2	1556	15.0
4%+	1020	15.8	1088	9.3	748	4.0	632	5.9
	6460	100.0	11700	100.0	18556	100.0	10424	100.0
Soil Drainage								
Well & Mod. Well	1560	24.2	1820	15.6	848	4.6	1348	12.9
Somewhat Poor	3968	61.4	7660	65.5	12732	68.5	4204	40.3
Poor & Very Poor	732	11.3	1924	16.4	4632	25.0	4648	44.6
Not Available	200	3.1	296	2.5	344	1.9	224	2.2
	6468	100.0	11700	100.0	18556	100.0	10424	100.0

*(HA) = Hectares
**(%) = Percent of Subwatershed

Determining Applicable Control Measures (Step 3)

The management, vegetative, and structural control measures listed in Section 3 were screened to identify measures which would be appropriate for the designated problem, and compatible with the soil and crop/livestock systems of the watershed.

Any measure that affects phosphorus movement is a possible candidate measure since phosphorus has been identified as a limiting nutrient in algae production in the lake. **Both soluble and adsorbed forms of phosphorus are known to contribute to the pollution problem.** Because in-stream and lake transformations of phosphorus are difficult to trace or predict, the relative contribution from soluble and adsorbed forms and any equilibrium relationship between the two forms have not been determined. Therefore, both overland flow and soil erosion/sedimentation pathway controls were evaluated. The effect of control practices on substances leached from the root zone is also reported because the control of overland flow may contribute to excessive leaching of non-adsorbed nitrate nitrogen.

Poor drainage of many Honeycreek soils limits the application of a number of the candidate measures listed in Section 3. Some of the practices which are of limited potential use in the watershed are listed below; limitations are discussed.

Improved Timing of Field Tillage Operations (NIA-4)[4]--

Many of the heavier soils in Honeycreek are fall plowed because it allows winter freeze-thaw cycles to help break up the soil and improve early spring drainage. In fact this fall plowing may be accompanied by a network of "dead furrows" which can increase surface drainage.

Using Mechanical Weed Control Methods (NIA-8) --

Most of the farming in the watershed is cash cropping with a distinct trend to larger units (Venice Township, 1976). Since these types of operations have a high opportunity cost for labor, herbicide treatment of weeds is used.

Reduced Tillage (NIA-9) and No Tillage Systems (NIA-10) --

Yield responses to reduced tillage are strongly influenced by soil drainage, degree of tillage, and mulch cover. Poorly drained soils in colder climates tend to decrease no tillage yields as compared with yields obtained using coventional moldboard plowing. A number of soils in Honeycreek would probably not respond well to no-tillage practices. Table 8 groups Honeycreek soils according to expected tillage responses (Triplett et al. 1973).

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[4] See Table 2 for description of practices.

Contour Farming (NIA-11) and Contour Strip Cropping (NIA-15) --

Although contouring is possible on most soils in the watershed, it tends to aggravate drainage problems where they exist. Also the complex slopes in many areas of the watershed make contouring difficult and decrease the efficiency of field operations.

Sod-Based Rotations (NIA-13), Permanent Vegetative Cover (NIA-16), Field Borders (NIA-17) and Buffer Strips (NIA-18) --

Because cattle and dairy operations in the watershed are of minor importance, the uses and markets for hay crops are limited. In addition, the trend has been to increase corn relative to hay in most feed rations which further decreases the need for hay.

Terraces (NIA-19) --

Both complex topography and poor soil drainage discourage the use of terraces.

Choosing The Unit of Analysis (Step 4)

The Honeycreek watershed has been conveniently divided into four physiographic regions. These areas are independent drainage units, thus water quality management can focus on each sub-watershed. **The following study analyses effects of applying control practices to both the entire watershed and to each sub-watershed area. The objective in choosing these areas is to demonstrate the difference between uniform and non-uniform levels of control within the watershed (see Appendix F).**

The unit of analysis could be broken down even further to the farm or field level. Case study II, the Yakima River Basin, will demonstrate this approach.

Establishing the Base Condition (Step 5)

Establishing the base condition has both physical and economic dimensions. Base physical conditions involve the variables described in Section III:

a. Precipitation and Temperature
b. Topography
c. Irrigation Requirements
d. Soil Type
e. Cropping Practice
f. Stream/Lake Characteristics

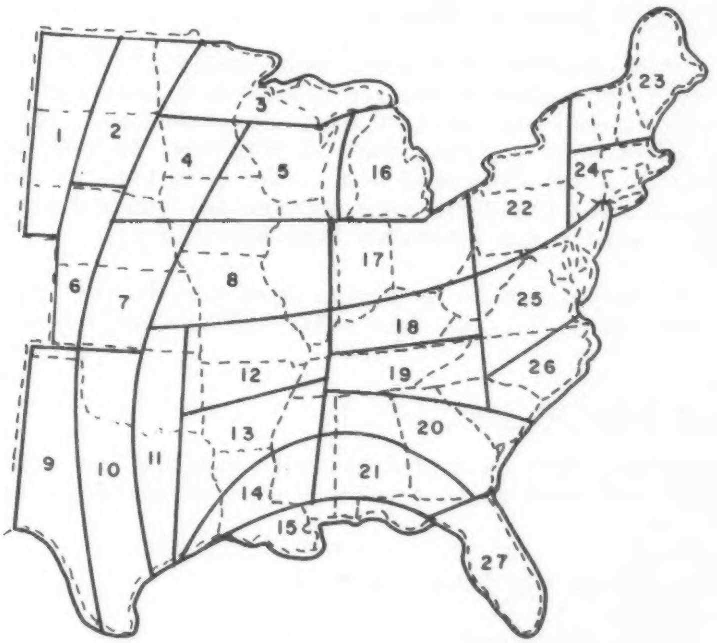
Each of these parameters and its effect on base pollutant losses are discussed below. Data sources and alternative ways of collecting the data are also given.

Precipitation and Temperature --

The Cornell Nutrient Simulation (CNS) model used in this case study to estimate overland flow requires daily precipitation and temperature data. Data used for Honeycreek were taken from a data file with information for 27 climatical areas in the eastern United States (refer to Appendix F). Figure 21 shows these regions. For each region the data included:

1. Average monthly precipitation and number of days with precipitation .01" .
2. Average January and July air temperatures.
3. Average dates of planting and harvest of principle crops in each region.

Figure 21. Climatological areas in Eastern United States with similar precipitation and temperature patterns.



The data for Honeycreek, included in Region 17, is presented in Tables 9 and 10.

TABLE 9. PRECIPITATION AND TEMPERATURE DATA, HONEYCREEK WATERSHED (REGION 17)

Month	Precipitation (cm)	Number of Days >.0254 cm	Average Temperature °C
January	6.45	14	-3.2
February	4.50	11	
March	8.03	13	
April	8.26	13	
May	8.74	12	
June	9.04	11	
July	8.33	10	23.1
August	7.11	8	
September	7.80	7	
October	6.65	8	
November	6.15	10	
December	5.74	12	
Total	86.89	129	

TABLE 10. CROP DATA FOR HONEYCREEK WATERSHED (REGION 17)

Crop	Planting Dates(P)	Harvesting Dates (H)	Average Planting Dates (P)	Average Harvesting Dates (H)
Barley (Spring) No Application				
Corn	5/1-6/15	10/10-11/30	5/25	11/5
Hay	5/15-5/25	9/5-10/5	5/20	9/20
Oats (sp.)	4/1-5/10	7/10-8/5	4/20	7/25
Rye (fall wc)	9/10-10/20	6/20-7/15	10/1	7/1
Soybeans	5/10-6/20	9/30-10/30	6/1	10/15
Winter Wheat	9/10-11/15	6/30-7/25	10/5	7/15

TABLE 11. PROPERTIES OF HONEYCREEK SOILS

Soil Group #	Texture Class	Hydrologic Group	Depth (ft) To Seasonal High W.T.	Permeability	PH	Available Water Capacity, lb/ft^3	Bulk Density lb/ft^3	Total P ug/g	Available P ug/g
1	silty clay loam	D	0 - ½	.6 - 2	5.6 7.3	.17 - .22		ug/g	ug/g
2	silt loam	C	2 - 4 floods	.6 - 2	6.1 7.6	.20 - .24	1.5	685	
3	silty clay loam	C	0 - ½	.6 - 2	5.2 7.3	.17 - .22	1.5		
4	loam	B	> 6	2. - 6	5.6 7.3	.14 - .18	1.5	848.08	23.90
5	loam	B	1½ - 3	.6 - 2.	5.6 7.3	.14 - .18	1.7		
6	loam	C	3/4 - 2	.6 - 4.5	5.4 7.3	.16 - .18	1.7		
7	loam, silt loam	C	4 to > 6	2. - 6.	5.6 7.3	.14 - .18	1.7		
8	silt loam	D	0 - ½	.6 - 2	5.1 6.5	.17 - .21	1.4		
9	silt loam	C	1½ - 3	.6 - 2.	5.6 7.3	.17 - .21	1.6		
10	silt loam	C	½ - 1½	.6 - 2.	5.1 7.1	.17 - .21	1.7	455.38	15.87

Topography --

Estimates of slope and slope length for the Honeycreek watershed were made using Conservation Needs Inventory (CNI) estimates (CNI, 1967). These estimates for the Honeycreek watershed were improved by an expanded sample and field verification during Lake Erie Wastewater Management Study (LEWMS) activities (Stem, 1978).

Appendix F provides estimated slope and slope length for the Honeycreek case studies and describes other methods of estimating slope and slope length, data sources and examples of each approach.

Soil Type --

In the Honeycreek watershed many of the 44 soil types have similar erodibility, expected corn yield, and drainage characteristics. Table 11 lists the ten groups which were used and the principle soil series in each group; properties of each of these ten soil groups are indicated. These properties and values were used in simulating nutrient losses.

The principal criteria used in grouping soils were drainage characteristics and response to no-till planting. Much of the information included in Table 11 was extracted from county soil surveys. The number of soil groups and criteria for grouping were influenced by the types and number of practices evaluated.

Once the soils were grouped it was necessary to determine the amount of land in each soil group for each watershed. Since county soil surveys do not compile data by drainage areas, this information is generally not available. The least time-consuming method of making this estimate is by grid sampling from soil maps. In the Honeycreek watershed 500 single hectare cells were sampled to determine the incidence of each soil type (Table 12). The number of grid cells sampled and their size can vary. The criteria used in determining the number of cells to be sampled and some examples of data derived for Honeycreek are included in the Appendix F.

TABLE 12. HECTARES OF CROPLAND IN EACH SOIL/SLOPE GROUP FOR EACH SUBWATERSHED

Soil Group	Slope* Category	Subwatershed				Total
		A	B	C	D	
1	1	63	198	737	1451	2249
2	1	583	383	835	33	1834
3	1	157	60	158	868	1243
4	1	94	5	24	-	123
	2	274	8	71	-	353
5	1	58	5	-	-	63
	2	72	-	-	-	72
6	1	422	13	228	-	663
	2	63	18	187	-	268
7	1	-	77	-	-	77
	2	5	288	-	-	293
	3	143	-	-	-	143
8	1	368	1527	2913	830	5638
9	1	58	-	-	-	58
	2	305	259	512	1059	2135
	3	313	310	6	185	814
10	1	1144	4031	8224	2040	15439
	2	2127	3733	4001	1351	11212
	3	-	190	-	-	190
Other		211	597	662	2606	4076
						47143

*Slope Categories: 1 = 0-2%; 2 = 2-4%; 3 = 4^{+}%

Cropping and Livestock Systems --

Knowledge of crops grown, common rotations and livestock systems are critical to understanding both the economic structure of farms and soil/water movement on cropland. Vegetative cover and crop residues strongly influence erosion and runoff potential.

No published data exist from which crops grown on specific soil management groups can be determined. For any given year, field sampling could be used. (This approach would be particularly attractive if slope length were to be determined in the field also.) The crop grown on a particular field or the rotation planned for a field, however, is subject to change. In livestock areas where feed rations are not changed greatly from one year to the next, crop acreages will not vary much. **In cash crop areas similar to those near Honeycreek, annual decisions made on crop acreage are based on previous year's prices and expected changes in market conditions during the next year.** These price variables make crop acreages in cash crop areas difficult to predict, so only rough approximations of expected crop acreages can be made.

A realistic portrayal of crop acreages in the watershed can be based on county statistics showing the ratio of crop acreage to total production in the county. Table 13 shows the livestock estimates derived from published agricultural statistics.

TABLE 13. NUMBER OF LIVESTOCK IN HONEYCREEK WATERSHED

County	Beef Cattle and Calves	Milk Cows and Heifers	Hogs
Crawford	2778	410	4142
Huron	441	132	760
Seneca	3883	850	5965
	7102	1392	10867

In the Honeycreek area a survey was recently conducted in a representative area of the watershed (Venice, 1976). Data from this survey were used to determine approximate acres of each major crop, and also livestock numbers (see Appendix F). This type of information is not available in most watersheds but a survey to collect these data can be performed by project personnel. Assistance can also be gained by contacting coopera- tive and county extension, ASCS and SCS offices.

Stream/Lake Characteristics --

The relationship between agricultural nonpoint source loads and instream or lake pollutant concentrations is often unclear. As discussed in Section 2, this missing link in water quality management generally does not allow precise estimates of the water quality benefits which will result from nonpoint source controls.

Analysis of alternative practices in the Honeycreek watershed focuses on the decrease in edge-of-field phosphorus, nitrogen and sediment loads. Because the watershed is intensively farmed it is assumed that control of these pollutants will decrease their concentrations in the stream. However, the precise nature and extent of the change is not now known.

Previous LEWMS research efforts in the Honeycreek watershed have resulted in the collection of a significant record of water quality data (Water Quality Data, 1978). Although these data do not solve the problem of relating agricultural nonpoint source controls to lake or stream quality improvements, they are useful for problem identification and hydrologic model calibration and validation.

Farm Economic Structure --

For the Honeycreek region, the costs and returns associated with livestock and crop production were estimated (Tables 14 and 15). Production costs included both fixed and variable costs. Capital investments, such as machinery purchases, are examples of fixed costs; labor, feed and fuel are variable costs. A detailed discussion of all cost estimates is found in Appendix F.

TABLE 14. DAIRY BUDGETS FOR THE HONEYCREEK WATERSHED

	Dairy* Cows ($)	Dairy† Replacement ($)
Variable Costs		
Conc. Protein (SB)	41.00	138.00
Minerals	14.00	6.00
Salt and Dicol	4.00	2.00
Milk and Starter		36.00
Sub-Total Feed Cost‡	59.00	182.00
Vet. and Med.	24.00	15.00
Breeding (DHI)	27.00	25.00
Utilities	26.00)	
Bedding	20.00)	15.00
Misc. and Supplies	20.00)	
Market Costs	72.00)	
Interest on Operating Capital	22.00	47.00
Total Variable Costs	270.00	284.00
Fixed Cost		
Labor	270.00	135.00
Interest	69.00	95.00
Cow/Calf Replacement§	215.00	100.00
	554.00	330.00
Total Costs	824.00	614.00

*Production 13,000 #/cow, receipts $1683/yr

†Replacement period birth to freshening, 36 mo.

‡Corn/hay feed requirements accounted for separately as part of farm group production

§Cow replacement = 0.35 x $614

TABLE 15. SOYBEAN BUDGETS FOR THE HONEYCREEK WATERSHED

	Soybean Conventional ($)	Soybean Minimum ($)	Soybean No-Till ($)
Variable Cost			
Seed	13.00	13.00	13.00
Chemicals[1]			
Fuel, Oil, Grease[2]	8.00	7.36	7.20
Repair and Misc.[2]	21.00	19.32	18.90
Labor[2]	15.00	13.80	13.50
Sub-Total Operating Cap.[3]	57.00	53.48	52.60
Interest on Operating Cap.[3]	2.71	2.54	2.50
Trucking[4]			
Fertilizer[5]			
Fixed Cost			
Management Costs[6]			
Machinery Depreciation	30.00	27.60	27.00
TOTAL	89.71	83.08	82.10
Chemicals			
Lorox	7.50	7.50	7.50
Lasso	7.50	7.50	7.50

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[1] Chemical - cost added in LP and interest

[2] Source: N. Rask and D.L. Forester, "Corn Tillage Systems - Will Energy Cost Determine the Choice", Agriculture and Energy. Academic Press, Inc. 1977. (Base price = Conventional till, Base price x .92 minimum till, Base price x .90 = no-till).

[3] Interest on Operating Capital - 9.5% for 6 mo. = .0475

[4] Trucking cost = $.01 per bu. Cost added in LP

[5] Fertilizer function of yield. Cost added in LP
P_2O5 (lbs) = 26.06 + .555 (yield) - .355 (P Test)
K_2O (lbs) = 80.556 + 1.333 (yield) + .75 (CEC) - .33 (K Test)

[6] Management - 29.5¢ per bu. Cost taken out in LP

Evaluating Control Measures (Step 6)

Cost and effectiveness of control measures were the major basis of evaluation. Initially, practices were screened for suitability in terms of physical and economic limitations and in terms of compatability with the present farm systems of the Honeycreek watershed.

Effectiveness --

Effectiveness was determined by comparing edge-of-field gross pollutant loading after practice implementation to that loading occurring under the base condition. No effort was made to estimate pollutant loadings entering the water body itself. This would require assessing the transformations of pollutants as they move from the field to the stream which would be extremely difficult. Once pollutants moved from the field they were assumed to reach the receiving water.

Field losses were estimated using the Universal Soil Loss Equation (USLE) for gross soil erosion, and the CNS model for average annual overland flow and nutrient losses. The commonly used USLE (Wischmeier and Smith, 1978) estimates average annual soil erosion based on a regional rainfall factor, the intrinsic erodibility of the soil, slope and slope length of a given field, the crop management system, and soil conservation support practices.

The Cornell Nutrient Simulation (CNS) Model developed by Haith and Tubbs (1978) consists of a hydrologic subroutine to calculate runoff and leaching losses and a loading subroutine to estimate losses of adsorbed phosphorus (P) and nitrogen (N), as well as losses of dissolved P and N to surface and subsurface flows. **The CNS model computes daily soil moisture concentrations and monthly soil nutrient budgets by quantifying all significant measurable inputs and outputs of water, nitrogen and phosphorus.** Daily precipitation and temperature data are replaced by probabilistic inputs corresponding to the appropriate geographic area. Runoff is calculated from these temperature and precipitation inputs by use of a modified form of the SCS Curve Number Equation. It is assumed that soil drainage is not limited by either a high water table or impermeable layers.

In the CNS model, two soil layers are modelled separately: a top layer of soil 10 cm thick and the 20 cm soil layer directly below this top layer. Organic nitrogen and total P are modelled for the top layer; inorganic nitrogen is modelled for both layers. Runoff losses, which include surface and subsurface losses, are assumed to occur from only the top layer of soil whereas percolation losses take place within both layers.

Nitrogen losses in runoff and percolation are calculated as the product of concentration and water volume, where concentration is determined from the average nitrogen level in the soil during the month. Because this model assumes that no losses of N via ammonification or denitrification occur after application, it will over-predict N losses in runoff or percolation over the long term. However, adjusting the initial fertilizer input to compensate for ammonification and denitrification losses may yield more accurate results.

Phosphorus losses in runoff are modelled in much the same way as N losses except that the adsorption coefficient (Ka) of the soil must also be considered. The coefficient affects soluble phosphorus availability. Phosphorus losses are typically underpredicted (particularly for intense storms) since the model does not account for the increase in quantity of soluble P associated with an increase in water volume.

The CNS model is applicable to any land area. It does not develop pollutant delivery ratios nor does it estimate in-stream quality parameters. However, it is a useful tool in comparing pollutant pathway control as a result of the implementation of nonpoint source control practices.

Cost --

In addition to the cost to install and maintain control measures, costs should include reductions in farm income resulting from investment in water pollution controls. While other industries are able, at least partly, to pass on cost increases to consumers, individual farm operators cannot (Nicol et al., 1974). For this reason **it was important to look closely at how pollution control influences a farm's cost structure. These changes in cost structure may mean appreciable decreases in income for certain farming regions or even place farm producers at a serious competitive disadvantage.**

The method used for estimating the income effects of control practices was linear programming (LP). Linear programming methods are particularly helpful in the evaluation of nonpoint source controls since both single practices and sets of practices can be evaluated. In addition, constraints can be established to limit runoff or erosion in certain subwatersheds or soil groups as well as the watershed as a whole.

A base LP solution maximizes or minimizes an objective function under certain restrictions (constraints) on the amount of land, labor and capital available to the farmer. For this study, **the objective function was to maximize net farm income.** The options for use and management of land are referred to in this analysis as 'activities'. The activities chosen for the LP model of the Honeycreek region reflected realistic alternatives available to the farms in the area. The number of choices was minimized since consideration of too many options creates an unwieldy array of alternatives. Net farm income was maximized by varying three sets of activities (management, vegetation, and structural controls) according to the following equation:

$$Y = k\ l\ m\ n\ (Aklmn - Nklmn)$$

Where: Y = net farm income

k = combination of soil group and slope. Ten distinct soil groups were considered and three slope categories (0-2%, 2-4%, 4%+).

l = tillage practices: conventional moldboard, chisel plowing and no-till planting.

m = crops: corn grain, soybean, wheat and meadow.

n = conservation practices: contour farming, crop rotations and diversion waterways.

Aklmn = hectares of land with conservation practice (n) applied to crop (m) and field type (k) using tillage system (l).

Nklmn = annual net revenue after producing one hectare of crop (m) for a particular combination of field type (k), tillage method (l) and conservation practice (n).

Constraints on sediment and nutrient losses can be expressed as:

$$(Aklmn - Pklmn) \leq loadklmn$$

Where:

Pklmn = pollutant loss (kg/ha) for a specific combination of field type, crop, tillage and practice application.

loadklmn = residual losses of sediment or nutrients for a particular combination of k, l, m, n.

Linear programming was used to compare the relative economic efficiency of alternative nonpoint source controls. These calculations were performed without consideration of cost-sharing. No changes in the price received or paid by farmers were assumed with the implementation of nonpoint source controls. In each case partial budgeting methods were used to determine net return (see Appendix F).

Developing an Optimal Control Strategy (Step 7)

There are a wide variety of control options ranging from traditional soil and water conservation structures, such as terraces and diversions, to changes in tillage systems, fertilizer application rates or crop rotations. In order to insure that a wide range of practices was considered, while at the same time minimizing the number of alternatives, practices were selected from each of the three categories mentioned earlier--management, vegetative and structural. Management options included changes in tillage practice and contour farming. Vegetative controls allowed one of four crops rotations to meet soil loss restrictions. Structural alternatives were reflected by the use of diversions to reduce slope length and thus, meet erosion restrictions.

To establish the relative improvement by a control practice set, it was compared to the base condition. Both loading estimates and income levels were calculated for the base conditions. It was assumed that for the base condition, those cropping systems which maximized profits would be selected. As pollutant loss constraints were placed on the watershed, the objective function continued to maximize profits using nonpoint source controls to reduce pollutant losses. These new income levels were compared to the base solution to determine pollutant control costs.

The linear programming model and the estimates for overland flow and leaching were linked in the following manner. The quantity of land in each soil management group having a certain tillage system, crop and conservation practice was determined for the base condition and for increasingly stringent levels of soil erosion control using linear programming methods. Total runoff, nitrogen and phosphorus losses were then estimated using the simulation model for each combination of activities at all levels of erosion control. The results indicated the change in farm income, associated reduction in gross soil erosion, reduction in runoff losses, and the associated losses of fixed and soluble nutrients.

Results --

Figure 22 illustrates the change in income with application of the three different control sets to meet soil loss restrictions in subwatershed A. A base solution for each linear programming (LP) run establishes the profit maximizing case with no soil loss restrictions. Base solutions differ depending on the type of tillage system assumed. Since reduced tillage systems greatly reduce erosion and have a relatively low cost they become part of the profit maximizing base solution for managerial controls.

From Figure 22, it is apparent that management controls, particularly changes in tillage practices, are a very efficient control strategy. At increasing levels of erosion control, vegetative and structural controls reduce income appreciably.

Figure 23 indicates how different management practices entered LP solutions. As soil erosion is limited, the area in subwatershed D which is treated with various tillage options changes. Both spring plowing and contouring enter the LP solutions at relatively high erosion limits while no-tillage enters at relatively low limits. Thus spring plowing and contouring are relatively more cost-effective than no-tillage in this case. However, in other watersheds with well drained soils one would expect the opposite.

Vegetative controls appear the most costly alternative since increased areas of wheat and meadow were needed to meet soil loss constraints (Figure 24). These lower value crops, although effective erosion control measures, result in appreciable decreases in return as shown in Figure 22. Structural controls[5] have a relatively high capital cost and result in some cropland taken out of production. Thus, although high value crops (corn and soybeans) can continue to be grown, this advantage is offset by capital charges and decreases in total production. Figure 25 shows the area of cropland with diversions as erosion constraints become more stringent.

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[5] Although only evenly spaced diversions (or "cross-slope drains") were considered, these controls act like graded terraces and are representative of practices which reduce slope length.

Figure 22. Relationship between gross farm income and soil loss constraint levels for three erosion control strategies.

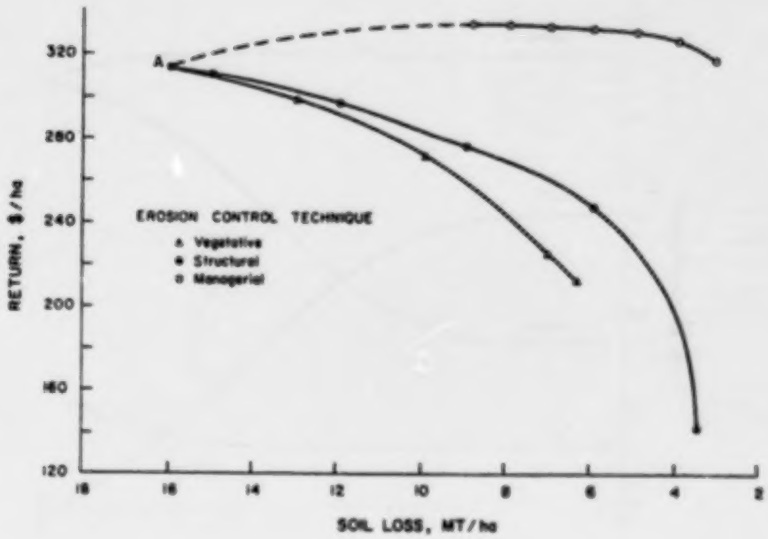


Figure 23. Management practices entering linear programming solutions - Subwatershed D.

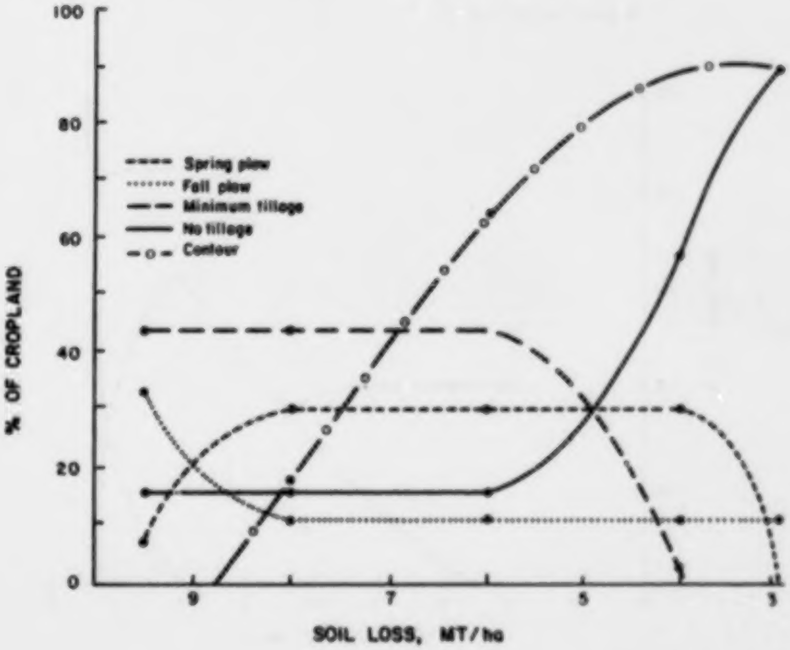


Figure 24. Linear programming solutions giving cropping areas for different soil loss constraint levels - Subwatershed A.

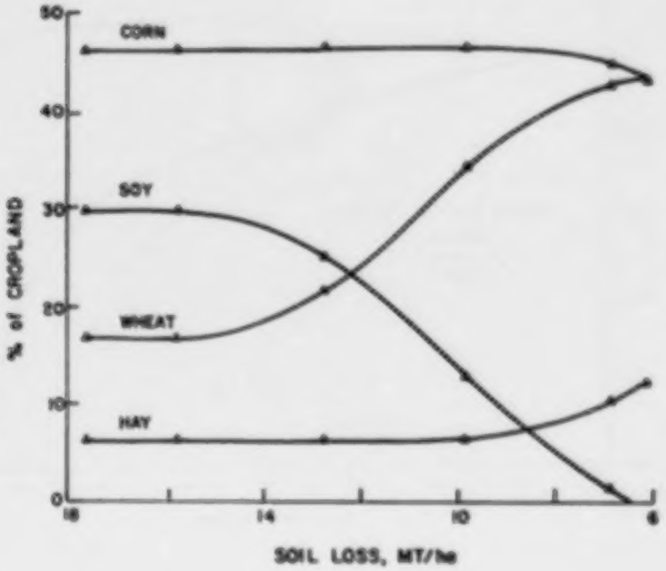
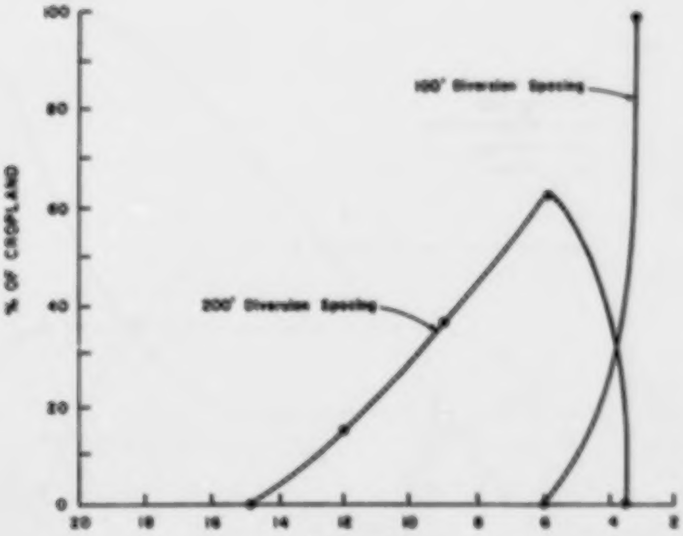
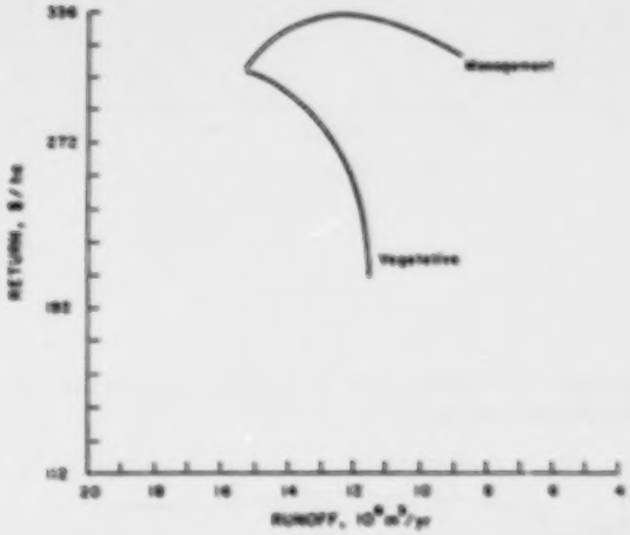


Figure 25. Linear programming solutions giving cropping areas for different soil loss constraint levels - Subwatershed A.



Runoff reductions are shown in Figure 26. They follow a trend similar to that of soil loss reductions: as control increases (i.e., return decreases) runoff decreases, with vegetative practices being less effective than management controls. Nutrients transported either with sediment or in surface runoff are effectively treated by both management and vegetative practices although management options are the least costly (Figures 27 and 28).

Figure 26. Changes in income for different levels of runoff controls.



The simulation model used to estimate runoff was not sensitive to the implementation of diversions so they were not evaluated as a management option.

Soil loss limits can be placed on the entire watershed as well as individual watersheds to allow for greater planning flexibility. In the latter case, for the same average soil loss, returns for a specified sub-watershed can be greater or less than those returns received when it is individually constrained. Figure 29 shows the variation in return for the four sub-watersheds at different soil loss constraint levels. One would expect this variation to increase appreciably for smaller sub-watershed units or where crop and livestock activities differ more.

Figure 27. Changes in income for different levels of dissolved phosphorus control.

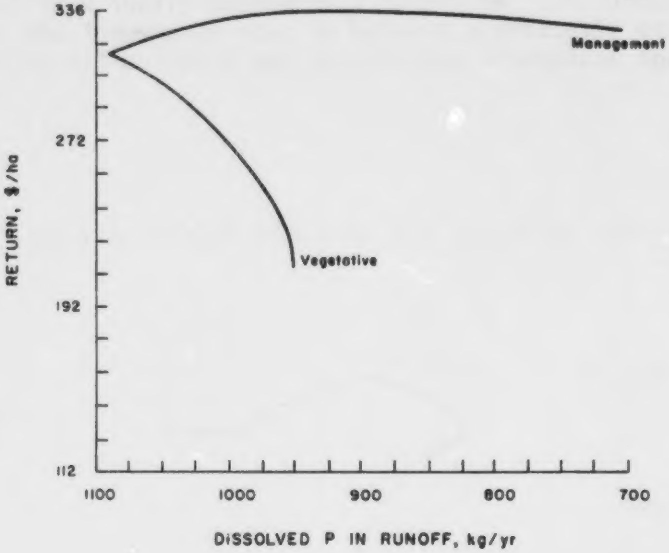


Figure 28. Changes in income for different levels of solid phase nitrogen control.

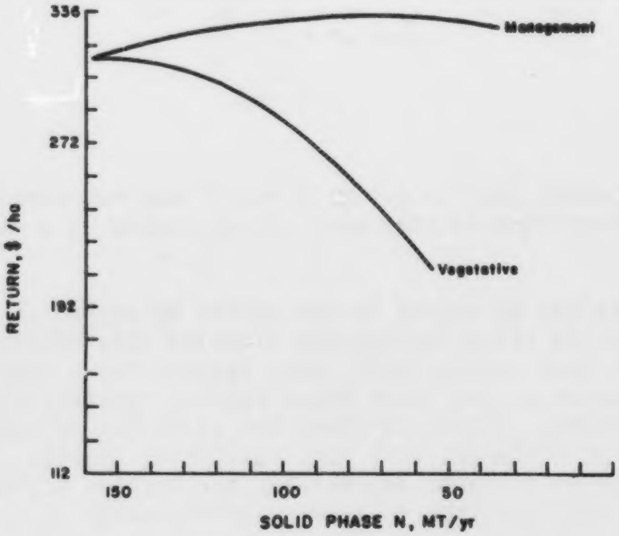


Figure 29. Control cost variations among subwatersheds.

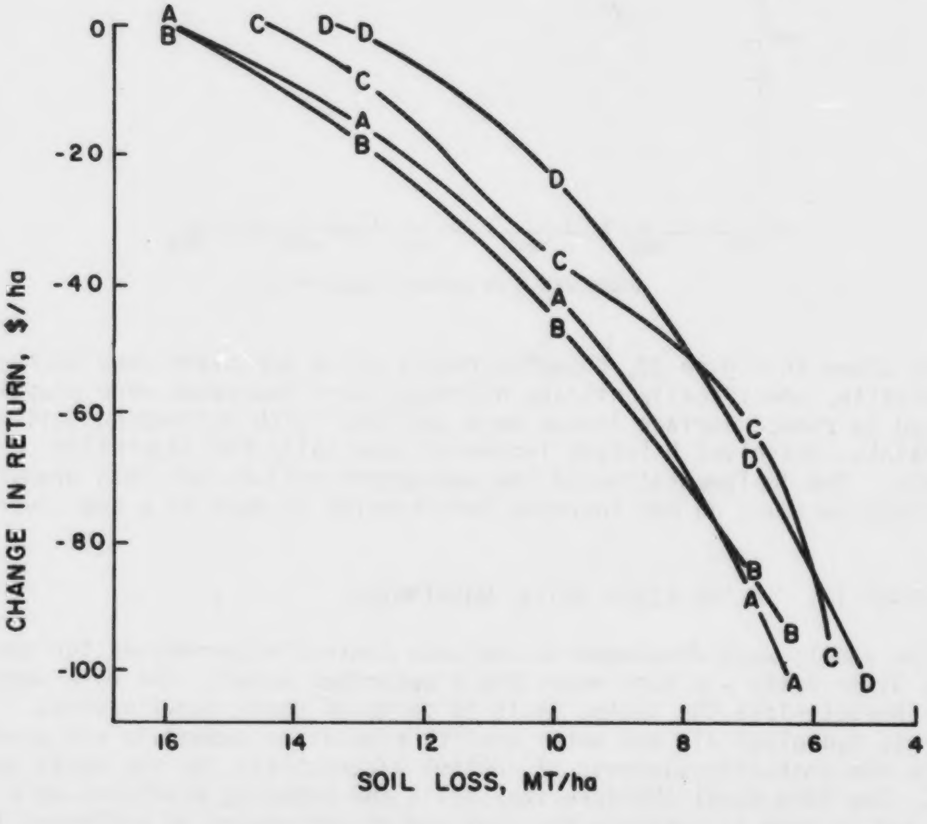
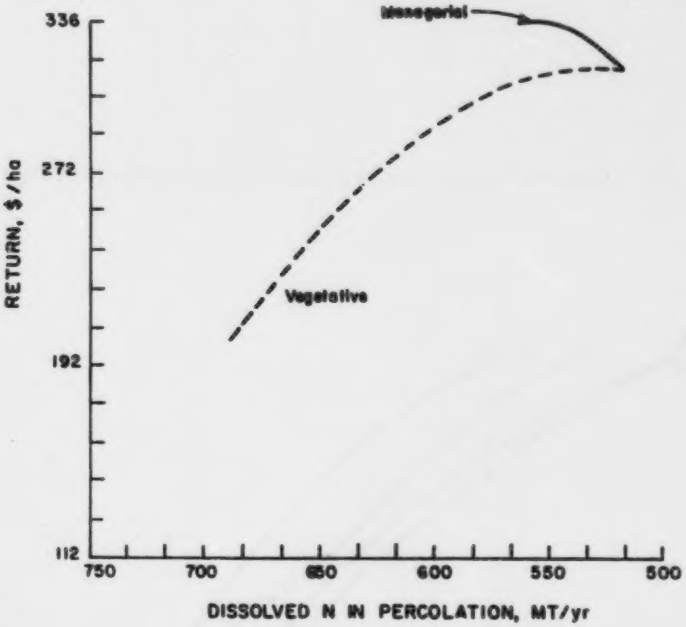


Figure 30. Changes in income for different levels of dissolved nitrogen control.



As shown in Figure 30, those nutrients which percolate down through the soil profile, specifically nitrate nitrogen, were increased when practices designed to reduce surface losses were applied. With increasing soil loss constraints, dissolved N losses increased especially for vegetative controls. The implementation of the management options was less dramatic since crop residues do not increase infiltration as much as a sod cover.

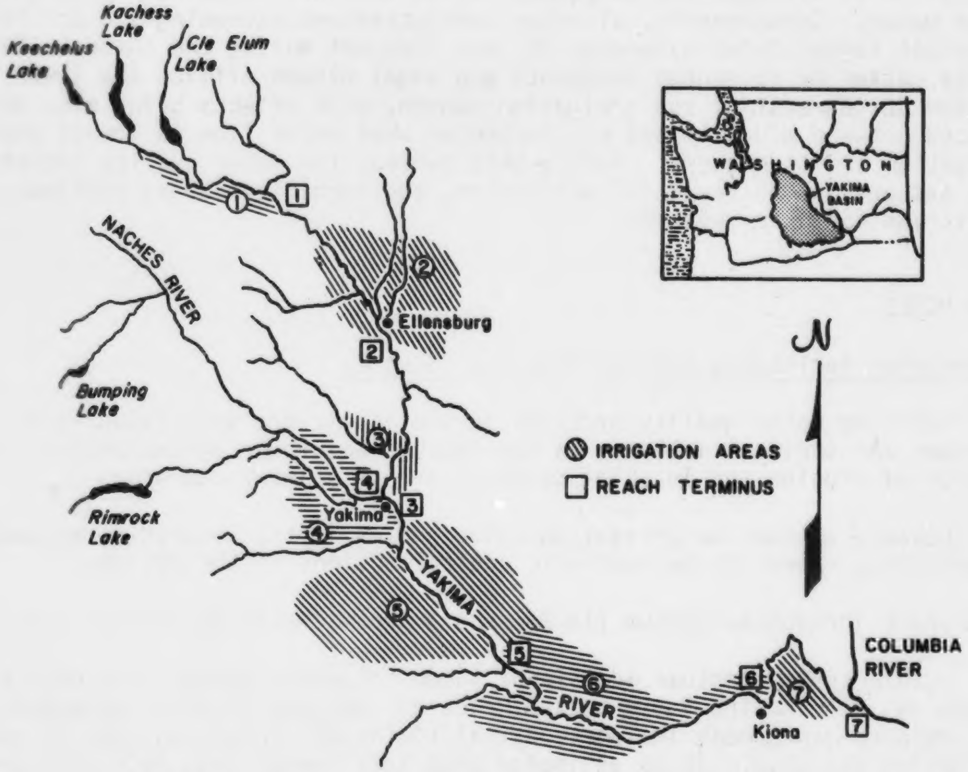
CASE STUDY II: YAKIMA RIVER BASIN, WASHINGTON

Two models were developed to evaluate control alternatives for the Yakima River Basin - a farm model and a watershed model. The watershed model characterizes the Yakima Basin in terms of seven subwatersheds. Agricultural, hydrological, and water quality simulation submodels are used to analyze the cost-effectiveness of control alternatives for the basin as a whole. The farm model characterizes soils and cropping practices on a farm scale and is used to evaluate the cost and effectiveness of different irrigation systems. Steps 1 and 2 below, Description of the Watershed and Problem Identification, include information which is relevant to both the watershed and the farm model. The rest of the evaluation process, Steps 3 to 7, is carried out for each model separately.

Description of Watershed (Step 1)

The Yakima River Basin lies in south central Washington and encompasses about 6,000 square miles (Figure 31). The basin contains approximately 450,000 acres of irrigated land, most of which was originally developed through a series of Bureau of Reclamation irrigation projects. There are many fruit orchards of less than 25 acres. The average farm size is less than 200 acres.

Figure 31. The Yakima River Basin, Washington.



Problem Identification (Step 2)

Water quality in the Yakima River generally has been excellent above the city of Yakima. River nitrogen concentrations have remained below the algae bloom level of .30 mg/liter during most of the year. Temperature has usually remained below the Washington Department of Ecology Class A standard of 65°F. Sediment loads have generally been small except during periods of heavy snow melt or precipitation. The Naches River has also generally met water quality standards.

Approximately one-half of the 288,000 ha-meters (2.4 million acre feet) of water diverted annually from the river is used above Yakima and one-half below Yakima. There is a considerably higher per hectare use of water along the upper reaches of the river. **Below Yakima, water quality grows progressively worse as a result of major irrigation diversions and large return flow volumes.** It is estimated that 80 to 90 percent of the water in the lower reaches (6 and 7 of Figure 31) during the late summer months is return flow from the upper reaches. **These return flows carry a higher concentration of nitrogen and suspended solids than are contained in virgin river water.** Consequently, nitrogen concentrations exceeding 1.0 mg/liter and water temperatures exceeding 80° are frequent during the summer. **Turbidity caused by suspended sediments and algal blooms afflict the lower reaches during most of the irrigation season,** with effects being most pronounced between mid-July and mid-September when water flow is lowest and irrigation use is highest. During this period, low water quality inhibits fish passage and recreational activities, and turbidity causes problems with downstream sprinkler systems.

FARM MODEL

Determining Applicable Control Measures (Step 3)

Existing water quality problems in the Yakima are associated with nitrogen and sediment delivery to the Natches and lower Yakima basins. Thus control of erosion and leaching pathways are of primary concern.

Because of the low irrigation efficiencies in the watershed, a number of practices appear to be realistic control options in the Yakima.

-- Cutback Irrigation System (IA-25) and Improved Water Management (IA-12)

This system employs additional labor to reduce stream size once the stream has reached the field bottom, plus an improved level of management. The improved management includes optimal timing of irrigation, and length of irrigation set time. It is estimated that total water loss from this system will be 50 percent of the loss from current irrigation practices.

-- Tailwater Reuse System (IA-26) and Improved Water Management (IA-12)

This set of practices modifies the current system by reusing the tailwater and employing an improved level of management as described for the above irrigation system. It is estimated that total base water losses can be reduced by 80 percent and that runoff losses will be negligible.

-- Automated Tailwater Reuse System (IA-26) with Gated Pipe (IA-25) and Remote Water Control (IA-12)

The practices included in this system are automatic reuse systems using gated pipe and remote sensing devices to control stream flow and set time. With these practices total water losses can be reduced by 80 percent from the base situation, and runoff losses will be negligible.

Side-Roll Sprinkler System (IA-29) With Improved Water Management (IA-12) --

See discussions in Section 3.

Solid Set Sprinkler System (IA-29) Operated with Improved Water Management (IA-12) --

See discussions in Section 3.

The farm model developed for the Yakima was also used to evaluate less traditional policy options. Although some of the options considered are contrary to existing legal and institutional practices in the watershed, they do provide a means of observing optimum adjustments to meet water quality standards (see Section 3, and Appendix B). Although some of these options are not practical at this time,they should be considered as possible future measures which could evolve over a long-term to meet water quality standards in a cost effective manner.

The policy options evaluated by the farm model include:

1. Constraining total nitrogen outflow from the farm.
2. Placing a per unit tax on nitrogen losses leaving the farm.
3. Making payments to the farmer for nitrogen and sediment pollution abatement.
4. Constraining total sediment outflow from the farm.
5. Placing a per unit tax on sediment outflow from the farm.
6. Constraining the total use of N fertilizer on the farm.
7. Constraining the total use of irrigation water on the farm.
8. Placing a per unit tax on N fertilizer applied.
9. Placing a per unit tax on water applied.
10. Paying the farmer for every hectare of close-growing crops produced.

The first five policies are administratively or legally infeasible at present, unless all return flow waters can be collected by a common drainage system and monitored. The policies can still be used, however, to determine a norm to which other policies can be compared. Taxing or constraining sediment loss remains potentially feasible, but difficult to implement for individual farms.

Choosing the Unit of Analysis (Step 4)

The farm model is convenient for demonstrating the effectiveness and cost of a number of different irrigation systems. The differences in soils and cropping practices in the Yakima are evaluated by sensitivity analyses.

Establishing the Base Condition[6] (Step 5)

The more than 2,000 farms in the basin are organized into several independent irrigation districts. Existing water rights in the basin have normally been sufficient for crop production. Thus, **few incentives have been provided by water costs or supplies to improve irrigation efficiency through better management and/or capital expenditures** (a notable exception being the drought period of 1976-77, when several irrigation districts were programmed to receive only enough water to keep perennial crops and a few annual crops alive). Consequently, surface or furrow irrigation is used on 60 to 70 percent of the irrigated land. The remaining acreage is irrigated by sprinkler irrigation methods adopted primarily in response to growing labor shortages and higher wages. A large proportion of the tree fruit acreage is irrigated with solid set sprinkler systems.

While some 80 different crops are commercially grown in the Yakima Basin, the economic returns and hydrologic characteristics of the basin can be represented adequately by 6 to 10 crops. A typical farm would grow no more than 3 to 5 crops.

Regions 1 and 2 (Figure 31) are dominated by forage crop production which supports an extensive livestock industry. In Region 2, small grains, sugarbeets, and vegetables are also grown. Region 3 is a relatively small area above the city of Yakima in which diversified crop production prevails. Region 4, lying along the Naches River, is dominated by sprinkler irrigated tree fruits. Regions 5, 6 and 7 are the largest and most intensively cultivated areas in the basin. Level land, rich deep soil, and favorable weather conditions make these regions suitable for almost all irrigated crops. Relatively large tracts of less productive land are neverthe less used for forage crops and pasture.

Gossett (1975) developed a linear programming model (see Appendix B) to represent an individual model farm in the Yakima River Basin. The model predicted the seasonal quantity of nitrogen leaving the farm in subsurface drainage and the amount of sediment carried by surface runoff. These losses were predicted for each of 5 crops, 4 fertilization rates, and 6 irrigation systems. Each crop therefore could be produced 24 possible ways.

A total of 560 acres of gently sloping land and a deep silt loam soil was assumed for the model farm. The crop mix included potatoes, sugarbeets, wheat, spearmint, and alfalfa. The farm model established a base irrigation system consisting of conventional surface irrigation methods using open ditches, siphon tubes and furrows. The model was then used to evaluate nitrogen and sediment losses for each of the control and policy options. Control alternatives were evaluated with respect to the effectiveness of the measures in controlling pollutant pathways and the farm costs associated with these controls. Costs included expenses for land and operator labor. Constraints were imposed to control crop rotations while maximizing net farm revenue for a single production year.

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[6] Physical and economic details of the watershed can be found in Gossett (1975).

Evaluating Control Measures (Step 6)

The capital and annual operating cost of the base irrigation system and the five alternative control measures are summarized in Table 16.

Deep percolation loss was assumed to be a constant percentage of the amount of water applied for the base system and option a. It was assumed to be the total loss for systems b and c, which used a form of pump-back irrigation. Deep percolation under sprinkler irrigation was assumed to equal the total loss minus 10 percent of water applied, which represents the loss to wind and evaporation. Table 17 shows the estimated irrigation efficiencies and deep percolation losses which were used in the farm model.

A base solution was obtained (see Table 18) when the farm was irrigated by the existing system, free of contraints. The only internal constraints were restricted crop acreages in order to represent realistic crop rotations. These constraints were: potato acreage 32 ha (80ac.); sugarbeet acreage 57 ha (140 ac.); alfalfa acreage 40 ha (100 ac); and spearmint acreage 57 ha (140 ac.).

When sediment and nitrogen outflows were unconstrained, the 560 acre farm produced a net revenue of $87,095 or $155.53 per hectare (Table 18). Total nitrogen leached through the root zone was calculated at 58.9 Kg/ha (52.5 lbs. per acre), producing a nitrogen concentration in the subsurface drainage water of 21.3 ppm. The base solution also had 1744 tonnes of sediment leaving the farm, or 7.69 mt/ha. A total of 160 cm of water was applied per ha. of farm land, with resultant deep percolation and runoff losses of 28.7 and 55.4 ha-cm., respectively.

The effects of alternate irrigation systems are compared with the base solution in Table 19. These solutions imposed no constraints or economic incentives to influence pollution abatement beyond those provided by the irrigation system. The solutions thus emphasized the marginal value of management, labor, and capital in reducing nitrogen and sediment waste loads. Comparing the existing system with system a, one can see that improved management would reduce nitrogen leaching by 25 percent and sediment yield by 62 percent at a total farm cost of $3,477, or $15.31 per ha. This cost arises because the additional labor costs more than the savings in fertilizer use. **The 3,900 hours required to irrigate the 227 ha (560 acres) with system a would require 3 to 4 full time irrigators. Operators would generally adopt more capital intensive irrigation systems in order to reduce required labor.**

Surface tailwater reuse, system b, was able to further reduce nitrogen leaching losses below those of system a, and to completely eliminate sediment discharge. **The reduced nitrogen losses may have been an artifact because deep percolation was assumed to be a constant proportion of the amount of water applied. With this particular system, water remains in the irrigation furrows for the same length of time as for the base siutuation, even though total water use is less because of the "reuse" of normal runoff losses. Total net revenue was increased slightly for this set of assumptions, because nitrogen fertilizer savings were greater than the increased costs of the tailwater reuse system.**

TABLE 16. CAPITAL INVESTMENT AND ANNUAL OPERATING COSTS OF THE BASE SYSTEM AND THE FIVE CONTROL ALTERNATIVES, YAKIMA RIVER BASIN

Irrigation Systems		Capital Investment[b]	Annual Operating Cost [a,b]
		$/ha	
BASE	Surface irrigation with open ditches, siphon tubes, and a base level of irrigation management	18.35	5.06
a.	Same as the basic system except for improved irrigation management, including additional labor to cutback furrow stream size.	18.35	5.06
b.	Surface irrigation with a collection pond and pump to reuse tailwater	44.86	19.32
c.	Surface irrigation with an automatic reuse system using gated pipe and moisture sensing devices	358.15	56.93
d.	Side-roll sprinkler with excellent irrigation management	395.20	47.97
e.	Solid-set sprinkler with excellent irrigation management	1593	181.72

[a] Excludes irrigation labor, water use charges, and electric power costs, but includes capital amortization costs and maintenance costs.

[b] Costs reflect 1974 price levels.

TABLE 17. ESTIMATED IRRIGATION EFFICIENCIES AND DEEP PERCOLATION LOSSES BY CROP AND IRRIGATION SYSTEM (YAKIMA RIVER BASIN)

Crop	Irrigation System					
	base	a	b	c	d	e
	Efficiencies (%)					
Potatoes	40.5	57.7	77.3	82.0	59.4	71.5
Sugarbeets	49.2	66.0	82.9	86.6	73.6	80.0
Wheat	46.3	63.3	81.2	85.2	70.5	78.1
Spearmint	40.5	57.7	77.3	82.0	64.2	74.4
Alfalfa	57.9	73.4	87.3	90.2	83.1	85.7
	Deep Percolation cm.					
Potatoes	32.8	23.1	21.6	16.3	38.1	19.1
Sugarbeets	33.5	24.9	18.8	14.2	20.3	11.4
Wheat	10.9	7.9	6.6	4.8	7.6	4.3
Spearmint	38.4	26.9	25.4	19.1	34.8	18.3
Alfalfa	34.8	27.4	16.3	12.2	9.4	5.6

TABLE 18. BASE SOLUTION FOR THE 227 HA. MODEL FARM, YAKIMA RIVER BASIN

	UNITS	TOTAL	PER HA
Net revenue	$	87,095	155.53
Nitrogen losses	Kg	13,337	58.82
Sediment yield	tonnes	1,744	7.69
Nitrogen applied	Kg	63,265	279.04
Water applied	ha-cm	36,297	160.12
Irrigation labor	hrs	1,990	3.55
Deep percolation	ha-cm	6,533	28.72
Runoff	ha-cm	12,580	55.41

A surface automatic reuse method, system c, would allow significant reductions in nitrogen fertilizer, water, and labor use, while maintaining constant production. **More efficient use of inputs would allow system c to be adopted at the relatively small cost of $3,026, or $13.34 per ha.** This is despite a required capital investment of at least $371 per ha., because nitrogen leaching was assumed reduced to 48 percent of the base level with this system. **The net income position would be slightly less than the base condition.**

The side-roll sprinkler, system d, proved to be uneconomic. Similar abatement reductions could be obtained at smaller private costs with other irrigation systems. Adoption of system d would cost over $9,000, while still producing 11,029 kg (24,319 lbs) of leached nitrogen. The solid set sprinkler, system e, could reduce leached nitrogen by 50 percent, but only at a cost of $32,899, or $146 per ha. **Both of the sprinkler systems would be inefficient in reducing nitrogen losses.**

The above comparisons are valid only under the conditions assumed for this model. Increases in the value of fertilizer, water, or labor could cause some shifts in comparative advantages among the various irrigation systems. Also, changes to more sandy soils or steeper slopes would automatically reduce the advantage of surface irrigation systems over sprinkler systems. **Under the conditions assumed, a farmer operating in the Yakima Basin with full technical and economic knowledge and complete mobility of resources would elect to irrigate with system b, the surface tailwater reuse system, which maximizes his net revenue.**

The model was also used to look at additional soil types and slope conditions. Figure 32 summarizes the marginal abatement costs for estimated nitrogen leaching on alternate soil types in the Yakima region. **Costs of abatement can quickly reach $4/kg of nitrogen loss abatement if nitrogen**

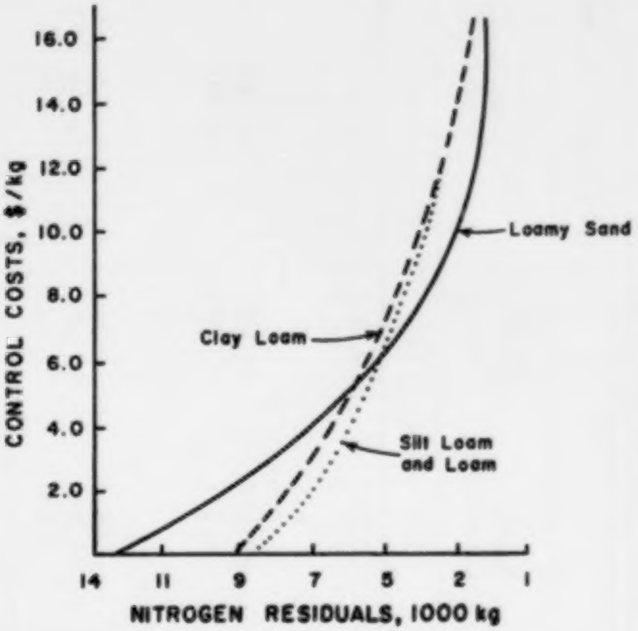
TABLE 19. COMPARATIVE IMPACTS OF THE EXISTING IRRIGATION SYSTEM AND FIVE ALTERNATIVE SYSTEMS FOR THE 227 HA MODEL FARM, YAKIMA VALLEY

		IRRIGATION SYSTEM				
	Base	Surface Cut-back	Surface Tailwater Reuse	Surface Automatic Reuse	Sprinkler Side-Roll	Sprinkler Solid-set
		(a)	(b)	(c)	(d)	(e)
Nitrogen Leached (kg)	13,377	10,007	8,963	6,969	11,029	6,704
Nitrogen Conc. (ppm)	21.3	21.3	23.9	24.3	23.8	26.7
Sediment yield (tons)	1,744	668	0	0	0	0
Sediment conc. (ppm)	1,388	1,408	0	0	0	0
Net Revenue ($)	87,095	83,618	87,801	84,069	78,034	54,196
Control Cost ($)*	0	3,477	706	3,026	9,061	32,899
Resource Use						
Nitrogen (1000 kg)	63.3	58.4	58.4	55.0	58.4	55.0
Water (ha-cm)	36,297	26,741	21,007	20,051	24,211	21,883
Labor (hrs)	1,990	3,980	1,990	80	796	80

*Reduction in initial revenue due to changing the irrigation system.

leaching is to be reduced below 50 percent of current levels for the model farms. These estimated abatement costs are based on most efficient combinations of new irrigation methods, management inputs, and crops for each level of abatement (see Appendix B).

Figure 32. Long-run marginal cost function for the abatement of nitrogen leaching for various soil types in the Yakima Valley.



Developing an Optimal Control Strategy (Step 7)

The ten policy options were first imposed on the farm assuming short-term planning, with investment in additional irrigation equipment not being allowed. The policies were also examined assuming long-range planning where irrigation system changes would be feasible.

Production costs were derived from cost studies conducted by the Cooperative Extension Service of Washington State University. Costs for irrigation labor, nitrogen fertilizer, and electric power were entered in the programming model at rates of $3.00 per hour, $0.44 per kg, and $0.082 per ha-cm ($0.085 per acre inch) of water, respectively. All costs and prices used for this analysis were representative of the mid-1970s.

Sediment yield is a function of only one production input - water. Thus, **controlling water use is the most economically effective method of controlling most sediment losses.** Under any policy to induce sediment abatement, such as taxing sediment, constraining sediment, constraining water use, or taxing water, the farmer would probably make the following adjustments: **As allowable sediment loss levels were reduced, the farmer would first convert his total acreage to system a, thereby reducing sediment outflow by 60 percent.** This adjustment would have a total cost of about $3,000. **To reduce sediment loss still further, the farmer would find it most profitable to substitute close growing crops for row crops.** A subsidy to the farmer would probably be required to induce such substitutions among crops. A sediment outflow from the farm of 363 tonnes (80 percent reduction) would cost about $17,000 for the combination of practices. Minimum outflow from the farm for the conditions examined (26 tonnes) would be obtained by eliminating row crops. **If sediment were the primary focus of abatement, it would be less costly in the long-run to turn to tailwater reuse systems or sprinkler systems.**

A policy of subsidizing the farmer for increasing acreage of close growing crops at the expense of high value row crops would necessitate an unreasonably large subsidy. Due to the greater returns from row crops as compared to close growing crops in this case, the farmer would probably not be willing to alter his crop mix until subsidies exceeded $346 per hectare (current return for row crops). Even this level of subsidy would not be particularly efficient in reducing sediment yield. As discussed in Section 3, it is probably not practical to attempt crop pattern adjustments through subsidy programs of this type.

WATERSHED MODEL

Determining Applicable Control Measures[7] (Step 3)

Applying NPS controls to the entire watershed enables consideration of a wider range of control practices and an overall assessment of control strategies to achieve water quality objectives. Water quality criteria of concern in the Basin include a maximum nitrogen concentration of .3 mg/liter, a maximum river water temperature of 70°F in August, and a maximum sediment loss of 22 Mt/ha (1 ton per acre) throughout the basin. **Where improved irrigation efficiency was needed to solve water quality problems, investments in new irrigation systems, improvement in irrigation management, or changes in crop mix or location of crop production within the basin were required.** The options include:

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[7] The watershed evaluation of nonpoint source controls is based on work by Pfeiffer (1975).

Tailwater Reuse (IA-27)[8], Sprinkler Irrigation (IA-29) and Improved Water Management (IA-12) --

This alternative would increase surface irrigation efficiency by 10% due to improved water management. The increases in efficiency are largely achieved by a 5% increase in tailwater reuse and sprinkler irrigation systems.

Tax on Nitrogen Fertilizer (IA-32) --

This policy was chosen because nitrogen loss is primarily a function of nitrogen application rate. The varying tax ranged from $0.22 to $1.54 per kg ($0.10 to $0.70 per pound) of nitrogen fertilizer.

Water Charge (I-33) --

This option imposed a charge on the use of irrigation water ranging from $0.62 to $3.08 per ha-meter ($5 to $25 per acre foot). Use of water for irrigation reduces river flow, which in turn increases both the effective concentration of pollutants and the river water temperature. Moreover, nitrogen loss is functionally related to the volume of deep percolation water, and sediment loss is functionally related to the volume of runoff water.

Uniform Reduction of Water Rights (IA-34) --

This practice imposed a uniform percentage reduction of water rights to all regions, with the reductions varying from 10 percent to 60 percent of current levels. Sales or exchanges of water rights between regions were not permitted. This policy would result in efficient resource allocation only if the demand for water is the same in all regions before and after water rights are reduced. The major advantage of reducing water rights is the fact that the policy does not require a direct income transfer from agriculture to the public sector.

Nitrogen Tax (IA-32) and Charge on Water (IA-33) --

This alternative combined a tax on nitrogen ranging from $0.44 to $0.88 per kg ($0.20 to $0.40 per lb.) with a charge on water ranging from $0.62 to $2.46 per ha-meter ($5 to $20 per acre foot). Since both water and nitrogen are contributors to pollution through irrigation return flows, it was expected that a combination of policies would be more efficient than policies directed at either individually.

Nitrogen Tax (IA-32) and Reduction in Water Rights (IA-34) --

Like the above option, this alternative combined a tax on nitrogen ranging from $0.44 to $0.88/kg ($0.20 to $0.40 per lb.) but with a reduction in water rights from 10 percent to 50 percent throughout the area.

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[8] Refer to Table 3.2 for a description of practices.

Change all Furrow Irrigation Systems to Either Sprinkler (IA-29) or Reuse Systems (IA-27)

See discussions on Sprinkler and Reuse Systems above.

Choosing the Unit of Analysis (Step 4) --

The watershed model characterizes both the agricultural system and the water quality of the entire Yakima River Basin. The river is divided into 7 reaches (Figure 31) with an associated land area corresponding to each river reach. In most cases, return flows from the farming region drain into the respective reach.

Establishing the Base Condition (Step 5) --

Table 20 shows two solutions that were used in the watershed model[9] to establish a basis for comparison of environmental improvement policies. Solution B_1 (base condition) constrained the crop area in all regions to existing levels. This solution most accurately reflects current conditions in the basin. Solution B_2 permitted regional crop production specialization, by allowing a 25 percent increase in row, fruit and vegetable crop area, a 50 percent increase in field crop area, and an unlimited increase in forage crop production for each region. Basinwide areas of each crop were still constrained to existing levels, however. **The results of solution B_2 were used as a base with which to compare all remaining policy results.**

Evaluating Control Measures (Step 6)

The cost effectiveness analysis of control practices utilized three mathematical models - an agricultural submodel, an hydrology submodel and a water quality simulation model. The agricultural model limits crop acreages, pollutant losses and practice application rates. These implicit constraints lead to abatement cost estimates. The hydrology submodel is a watershed mass balance of water flows including precipitation, runoff, and irrigation diversions for each subwatershed. Finally the water quality simulation model relates agricultural and irrigation practices on cropland to gross pollutant loading. Figure 33 shows inputs and outputs of each model and how they are linked when used to make policy decisions.

The Agricultural Submodel --

The agricultural submodel for the river basin included 10 crops, 3 irrigation systems, 11 regions and subregions, and 4 levels of nitrogen application for most crops. In order to permit some degree of regional specialization, row crop and fruit crop acreages were permitted to increase 25 percent and 50 percent, respectively, within each region. The total area of these crops within the basin, however, was constrained to present levels. The area of forage crops was not specifically restricted. **The model reflected surface and subsurface return flows from crop activities within each region.**

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[9] For details of the model and input data used see Pfeiffer (1976).

TABLE 20. INCOME, RESOURCE USE, AND RESULTANT WATER QUALITY FOR SOLUTIONS B_1 AND B_2 , YAKIMA RIVER BASIN

Item	Unit	Solution	
		B_1	B_2
Net crop income	$1000	105,950	106,910
Area irrigated	1000 ha	183	183
N applied, total	1000 Kg	42,894	42,879
N applied,	Kg/ha	234	234
N lost, total	1000 Kg	7493	7433
Water diverted	1000 ha.-m	296	294
Flow at Kiona, August	1000 ha.-m	13	12
N concentration, season[a]	mg/l	0.70	0.65
N concentration, August[a]	mg/l	0.93	0.87
Sediment loss, total	1,000 Mt	610	714
Sediment loss	Mt/ha	3.34	3.90
Maximum temperature	°C	24.1	24.3

[a] Maximum concentration

Nitrogen loss functions, sediment loss functions, and irrigation efficiency relationships (see Appendix B) for various irrigation systems are examples of the data requirements for this type of analysis. **Sediment losses were adjusted for factors such as crop cover, tillage practices, method and rate of irrigation, slope and soil type, and overall management level.** Water rights in the river basin were assumed to represent maximum allowable diversions of water. In most cases, water quantities are more than sufficient to supply crop needs under current irrigation practices. By imposing constraints and/or higher prices on inputs used by the agricultural sector, abatement effectiveness and the distribution of abatement costs resulting from alternative policies could be estimated and compared.

Hydrology Submodel --

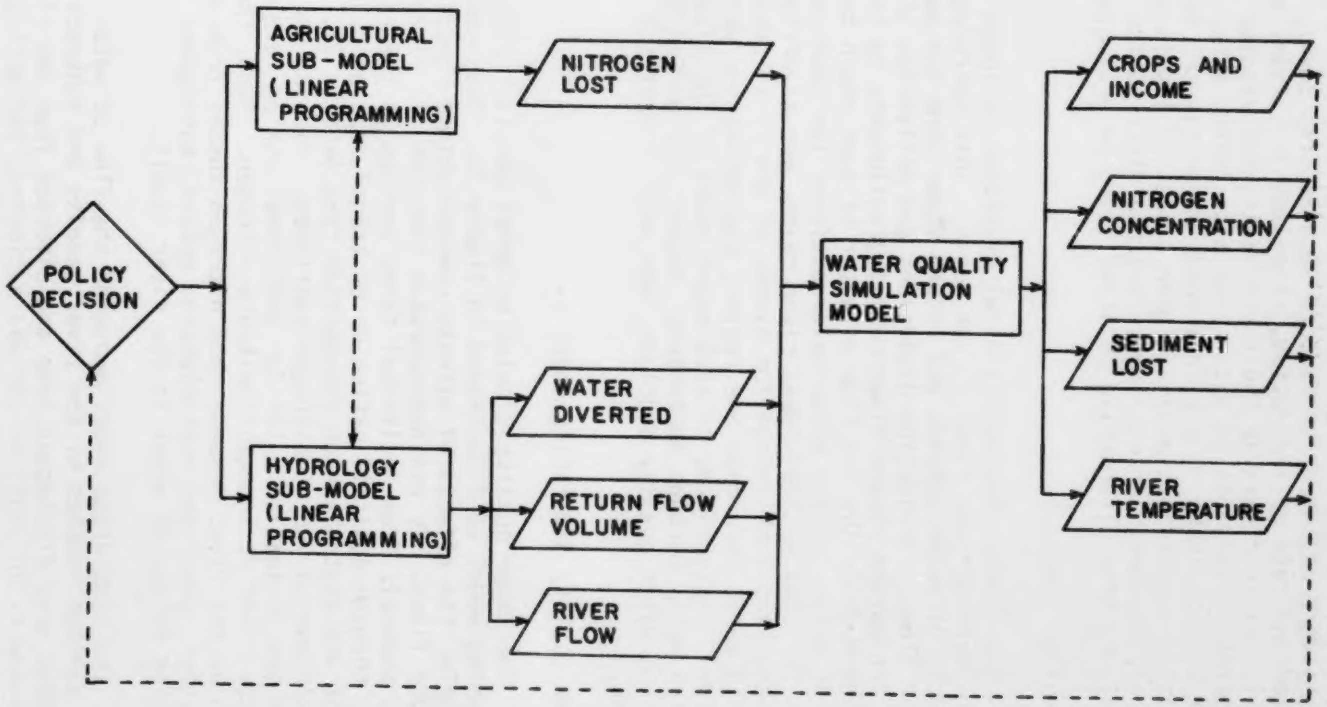
The linear programming model developed included a hydrology submodel representing river flows in the basin. **This hydrology model reflected effects of water demands and return flows from the agricultural submodel on river flows. Irrigation diversions and deliveries at each reach terminus, and irrigation return flows carrying pollutants to the river, were included in the model.** The net flow of water at each reach terminus was taken as the sum of water inflows minus water outflows for that reach. Natural inflows were included by individual river reach, and diversion rights were allocated by canal for each irrigation system of the river basin. In cases where canals serve more than one region, the activities were appropriately subdivided. Water flows in each major reach of the river were input for the period April through September. August, the period of lowest flow and most serious water quality problems, was used to meet the water quality standards.

Water Quality Simulation Model --

The water quality simulation model was linked with the linear programming model as illustrated in Figure 33. **This model measured,** for example, **the effects of nitrate concentrations contributed by irrigation return flows.** It was demonstrated that not all nitrogen entering return flow channels from individual farms arrives at the river. Some nitrogen is lost through denitrification or by transformation to organic forms during plant and phytoplankton consumption (see Section 2). Once in the river, phytoplankton use of nitrogen continues. Part of the nitrogen is diverted with the irrigation water for additional use on farm land, and part remains in the river as inorganic nitrate nitrogen. Thus, the nitrogen concentration in the river depends upon nitrogen losses from upstream farms, denitrification, plant and phytoplankton uptake, subsequent irrigation diversions, and the volume of water in the river itself.

The simulation model measured the flow of water and nitrogen throughout the various reaches of the river, adding and subtracting nitrogen and water as they were discharged into and diverted from the river. A pollutant delivery ratio (PDR) of .32 was estimated, reflecting the nitrogen lost from farms which actually enters the river in nitrate form during the irrigation season. During August, the PDR is reduced further to approximately .24, because of plant and phytoplankton uptake.

Figure 33. Flow diagram of models used to evaluate alternative controls in the Yakima River Basin.



Results --

Table 21 summarizes the policies evaluated which met the prescribed water quality standards. The table includes base solution 2 (B_2) for comparison. Two measures of abatement costs were used. "Producer cost" measured the reduction of farm income caused by abatement policies, reflecting the immediate and direct impact on agriculture. "Net social cost" measured the public or total cost of abatement policies. The two differed if a transfer of income from agriculture to the public (a tax) or from the public to agriculture (a subsidy) was involved. Comparing the social costs of alternative policies is a more realistic measure of their relative economic efficiencies (see Appendix F for a further discussion of this topic).

Tax on Nitrogen Fertilizer (IA-32) -- As expected, nitrogen application rates declined as the tax increased. Fertilizer use was reduced on all crops at the higher tax rates, but reductions on the irrigated pasture (a relatively low-value crop) were most pronounced. A nitrogen tax above $0.88/kg ($0.40 per lb.) resulted in no nitrogen fertilization of pasture in the basin. Water diversions declined with irrigated acreage, so less production of low intensity pasture caused August river flow volume to increase. Nitrogen concentration and water temperature goals were finally met with a nitrogen tax of $1.32/kg ($0.60 per lb.).

Water Charge IA-33) -- Irrigated pasture was once again the crop most affected, though alfalfa acreage also declined sharply at the $162/ha-m ($20 per acrefoot) rate. The area of other crops remained relatively unchanged, despite changes to more efficient irrigation methods.

Uniform Reduction of Water Rights (IA-34) -- Under this policy, as would be expected, irrigated acreage declined rapidly as water rights were reduced, primarily affecting crops in the order of their value. Water conserving irrigation systems were also implemented with increasing frequency as water rights were reduced. Water rights reductions of 30 percent or more even caused fruit production to decline in some areas.

Prohibiting Surface Runoff (IA-29, IA-27) -- The result was almost no change in cropping pattern and only a small reduction of income compared with the base solution. Sediment loss was completely eliminated, but river flow volume, nitrogen concentration and water temperature changed little. This solution illustrated a policy directed at a single effluent, sediment, without affecting other major pollutants in the river basin. This demonstrates that it is possible to completely abate one pollutant in such a river basin without significantly affecting other water quality parameters. The major shortcoming of this policy was the fact that it had almost no impact on either nitrogen concentration or water temperature, which are also serious problems in the basin.

Developing an Optimal Control Strategy (Step 7)

Optimal abatement is possible either with taxes or with constraints on inputs which contribute to a particular pollutant. Nitrogen content of return flows, for example, would be most efficiently controlled with a

TABLE 21. SUMMARY OF THE BASE SOLUTION AND OF THE POLICIES WHICH MEET A PROPOSED MAXIMUM RIVER WATER NITROGEN CONCENTRATION OF 0.3 MG/L AND A MAXIMUM RIVER WATER TEMPERATURE OF 21°C

ITEM	UNIT	BASE SOLUTION B_2	CONTROL ALTERNATIVES[b]						
			IA-32	IA-33	IA-34	IA-32+IA-33	IA-32+IA-33	IA-32+IA-34	IA-32+IA-34
N tax	$/kg	---	1.32	---	---	.44	.88	.44	.88
Water charge	$/ha-m	---	---	163	---	81	41	---	---
Water rights, reduction	%	---	---	---	50	---	---	40	30
Crop acreage	1000 ha	183	170	106	117	120	120	130	150
Crop sales	$1,000	303,906	264,544	260,537	251,905	265,926	264,933	261,734	269,060
Net crop income	$1,000	106,910	62,972	78,959	90,317	75,233	68,350	81,757	72,796
Net producer cost	$1,000	---	43,938	27,951	16,593	31,676	38,560	25,153	34,114
Net social cost	$1,000	---	13,164	11,894	16,593	9,664	10,149	12,431	10,508
N applied, total	1000 ha	42,995	23,260	31,898	30,976	27,257	26,482	28,848	26,765
N applied per acre	kg	95	55	122	107	92	90	90	72
N lost, total	1000 kg	7,433	3,337	4,696	4,435	3,932	3,461	4,200	4,060
Water diverted	1000 ha-m	294	236	131	150	165	167	180	207
Flow at Kiona, August	1000 ha-m	12	22	31	28	27	27	21	23
N concentration, season[a]	mg/ℓ	0.65	0.26	0.28	0.29	0.26	0.25	0.28	0.27
N concentration, August[a]	mg/ℓ	0.87	0.28	0.28	0.30	0.27	0.26	0.30	0.30
Sediment lost, total	1000 Mt	714	495	83	97	206	248	115	434
Sediment lost, (irrigated area)	Mt/ha	8.90	2.91	0.78	0.83	1.73	2.06	0.90	2.89
Sediment lost, (irrigable area)	Mt/ha	3.90	2.71	0.45	0.52	1.12	1.35	0.47	2.38
Maximum temperature	°C	24.2	21.0	19.7	19.9	20.3	20.3	20.3	20.6

---

[a] Maximum Concentration

[b] See page 252 for description of control alternatives and Table 3 for a description of control practices.

policy affecting both nitrogen fertilizer and irrigation water use. Water temperature, on the other hand, is a function primarily of river flow volume, thus policies reducing water diversions would be most efficient in affecting this quality parameter. Sediment loss, a function of surface water runoff, would be most efficiently controlled by irrigation systems which reduce or eliminate runoff volumes.

Table 22 shows that improved management (IA-27, IA-29 and IA-12) was unable to meet the water quality standards which were sought for this river basin. Each of the other solutions, d through h, was able to meet water quality standards at varying levels of efficiency. In all cases, the net cost for meeting water quality standards in the river basin were rather large. **The most efficient policy was solution g. It included a combination of water charge and nitrogen tax** in order to meet desired water quality standards at a net cost of $9 million for the river basin. The least efficient policy in meeting all quality standards was solution d, which taxed only nitrogen. This policy resulted in a net social cost of over $1 million. Net farm income would actually be decreased by even larger amounts in each case, due to the additional charges to farmers for water and fertilizer.

TABLE 22. INCOME, RESOURCE USE, AND WATER QUALITY IMPACTS ASSOCIATED WITH IMPROVED MANAGEMENT (IA-27, IA-29 + IA-12)

Item	Unit	Base Solution B2	IA-27 + IA-29+IA-12[b]
Net crop income	$1,000	106,910	108,332
Irrigated area	1,000 ha	183	183
N applied, total	1,000 kg	42,379	42,907
N applied per unit area	kg/ha	234	234
N lost, total	1,000 kg	1,433	6,454
Water diverted	1,000 ha-m	294	271
Flow at Kiona, August	1,000 ha-m	12	14
N concentration, season[a]	mg/l	0.65	0.54
N concentration, August[a]	mg/l	0.87	0.69
Sediment loss, total	1,000 mt	714	341
Sediment per irrigated acre	mt	1.58	.75
Maximum temperature	°C	24.2	23.3

a Maximum concentration.

b See Table 3 for description of control alternatives and practices.

The net social cost figures include required subsidies that must be paid to agriuculture in order to meet specified water quality standards. **To induce similar changes in cropping patterns, nitrogen fertilization levels,**

or irrigation systems through subsidy programs would require annual costs equal to net social costs. It is doubtful that benefits achieved through water quality improvements to such levels would equal the costs imposed.

Although it had the highest social cost, solution f had the lowest producer cost. It was some $8.6 million less expensive to the producers than the next least expensive policy, solution h. The fact that no taxes or charges were levied accounts for the low costs to producers imposed by solution f.

If subsidies could not be used to meet environmental standards, a reduction of water rights (IA-34) would probably be considered the next most acceptable solution by the farm sector, though the capital investment required for improved irrigation systems would be large. The only policy not requiring extensive capital investment for irrigation systems would be solution d, although this policy had the highest producer costs of any policies evaluated. It would not likely be a politically acceptable way of meeting the proposed environmental standards.

Because of their relatively low value, the production of irrigated pasture, alfalfa, and corn was the first to be reduced by all abatement policies. The livestock industry, which was not included in the analysis, would decline markedly as feed production declined under such policies. **Farm income would also be affected to a larger degree than indicated by the model results, because livestock was not included in the analysis.**

Labor employment in the farm, agricultural supply, and agricultural processing sectors would decline under all policies analyzed. In addition to farm output, the adoption of improved irrigation systems would lower irrigation labor demand. Reduced farm income and its impact on the economy would also diminish non-farm employment opportunities.

The watershed model showed that it is possible to improve water quality in such a river basin by controlling agricultural inputs or activities. Improvement to a point where water quality is suitable for virtually all uses of the Yakima River required a reduction of farm income ranging from 16 to 41 percent, depending on the policy employed. In addition to reduced farm income, these policies would impose burdens on the agricultural sector in the form of reduced land values, diminished livestock numbers, decreased activity employment, and increased capital investments in new irrigation systems.

It should be noted that the costs of abatement in this analysis are valid only as relative values among alternative policies. The real cost of any policy might vary from that presented here because of changes in crop input cost, crop prices, administrative program cost, and level of abatement desired. (See Section 3.)

The historic pattern of water use in the Yakima River Basin has promoted irrigation methods and practices which are not water conserving. The policy of providing water at a fixed cost per unit area encourages the substitution of water for management, labor, and other farm inputs. This

has led to unnecessarily high amounts of surface runoff and deep percolation loss, depleting the river flow and resulting in water quality degradation. Under these circumstances, changes in water use policies would greatly improve irrigation efficiency and river water quality.

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APPENDIX A

ESTIMATING NONPOINT SOURCE SEDIMENT AND NUTRIENT LOADINGS FROM NON-IRRIGATED CROPLANDS

L.J. Tubbs and D.A. Haith

SECTION 1

INTRODUCTION

The selection of best management practices (BMPs) for agricultural systems should be based on considerations of the economic, institutional, and water quality impacts of each management scheme. **This report provides a means for estimating the amounts of crop nutrients which may enter surface and groundwater systems from various cropping situations in the eastern and central United States.** These estimates may be used directly to predict average, annual nutrient loadings from an existing or proposed cropping system, or they may be combined with economic models to determine the distribution of management practices which efficiently meets water quality objectives. **Although the nutrient loading estimates provided in this report are for individual fields under a single crop and cropping practice, a farm or watershed system may be analyzed by summing the loading estimates for each field in the system.**

Several mechanisms for nutrient loss from cropland into receiving waters are described in Figure A-1. These mechanisms may be divided into field processes, transport or delivery processes, and stream processes. Nutrient simulation models are often divided along these lines, resulting in separate predictions of edge-of-field loadings, nutrient and sediment transport, and surface water impacts. This report is concerned only with the first two processes, which will be considered separately. Referring to Figure A-1, direct runoff (surface runoff plus interflow or subsurface runoff) may contain dissolved forms of nitrogen (N) and phosphorus (P), and provides a means for transport of solid-phase N and P in eroded soil. Percolated water may carry dissolved nutrients below the root zone to underground aquifers. Dissolved N in groundwater may later reappear with baseflow in streams. Dissolved P in deep percolation does not usually reach surface waters due to the adsorption of phosphorus by soil particles below the root zone.

The most general method for estimating nonpoint source nutrient losses is through the use of mathematical simulation models. However, such models can be difficult to apply since they require a great deal of data and intimate knowledge of the soil and crop environment being modelled. Furthermore, available simulation models typically have high start-up costs associated with specialized computer programs. In order to capture the flexibility of simulation within an approach that can be applied relatively easily by a water quality planner, **the Cornell Nutrient Simulation (CNS) model was run for ten-year periods using cropping and meteorologic data from 27 climatic areas in the eastern and central U.S.** (Figure A-2). Within each area, variations in soil water and fertility parameters were made, and the **results obtained were average annual water and dissolved nutrient losses to edge-of-field.** To facilitate their usefulness, the simulation results **were summarized as predictive equations for runoff, percolation, and nutrient concentrations. Independent variables in the equations are curve number (as in the U.S. Soil Conservation Service's runoff equation), fertilizer applications, and soil nutrient levels.** These predictive equations are analogous to the Universal Soil Loss Equation (USLE), although they are based on simulated rather than actual field experiments.

Although comparable simulation procedures could have been used to derive general predictive equations for solid-phase nutrient losses, simpler methods are available for estimating average annual losses. **Since the USLE provides estimates of average erosion rates, these soil losses can be multiplied by N and P concentrations in sediment to determine annual solid-phase nutrient losses.** Concentrations in sediment are equal to *in situ* soil concentrations multiplied by enrichment ratios to account for the selective erosion of small organic matter and clay particles which have higher nutrient contents than other soil constituents. This procedure for estimating solid-phase nutrient losses assumes that levels of soil N and P do not change significantly from year to year.

The remainder of this report consists of three sections and several appendices. **Section 2 documents the simulation experiments and their results which were used to derive location-specific predictive equations for runoff, percolation, and dissolved nutrient concentrations. Section 3 combines these results with the USLE to provide a general methodology for estimating nonpoint source nutrient losses and evaluating potential best management practices for their control. The methodology is demonstrated in the final chapter by analyses of selected sample fields as well as an actual watershed (Honey Creek, Ohio). The appendices describe the CNS model and its application to the 27 climatic areas.**

The methodology in this report presumes familiarity with, and access to, two primary reference sources:

1. Stewart, B.A., Woolhiser, D.A., Wischmeier, W.H., Caro, J.H., and M.H. Frere, *Control of Water Pollution from Cropland - Vol. I and II*, Report No. EPA-600/2-75-026a (Vol I), EPA-600/2-75-026b (Vol II), U.S. Environmental Protection Agency, Washington, D.C., 1975, 1976.

2. Wischmeier, W.H. and D.D. Smith, *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning*, Agriculture Handbook No. 537, U.S. Dept. of Agriculture, Washington, D.C., 1978.

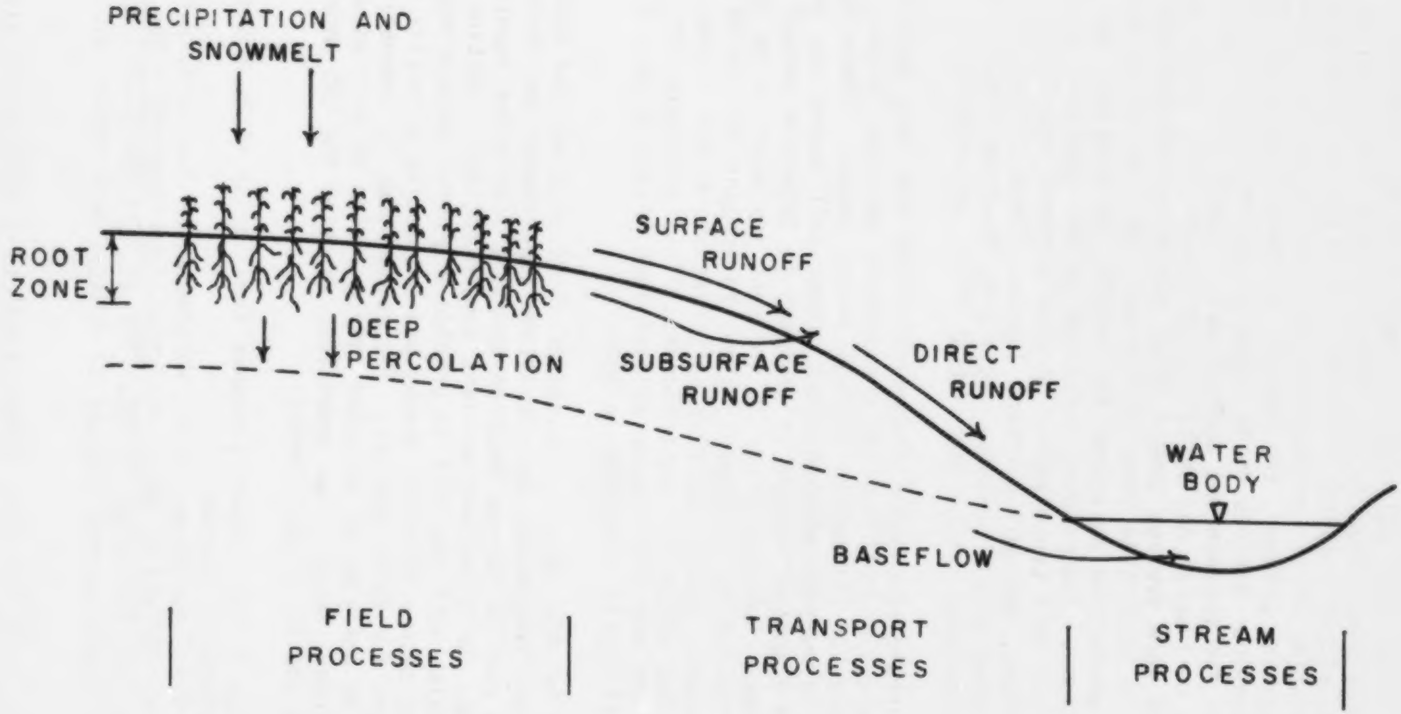


Figure A-1. Mechanisms for Pollutant Loss

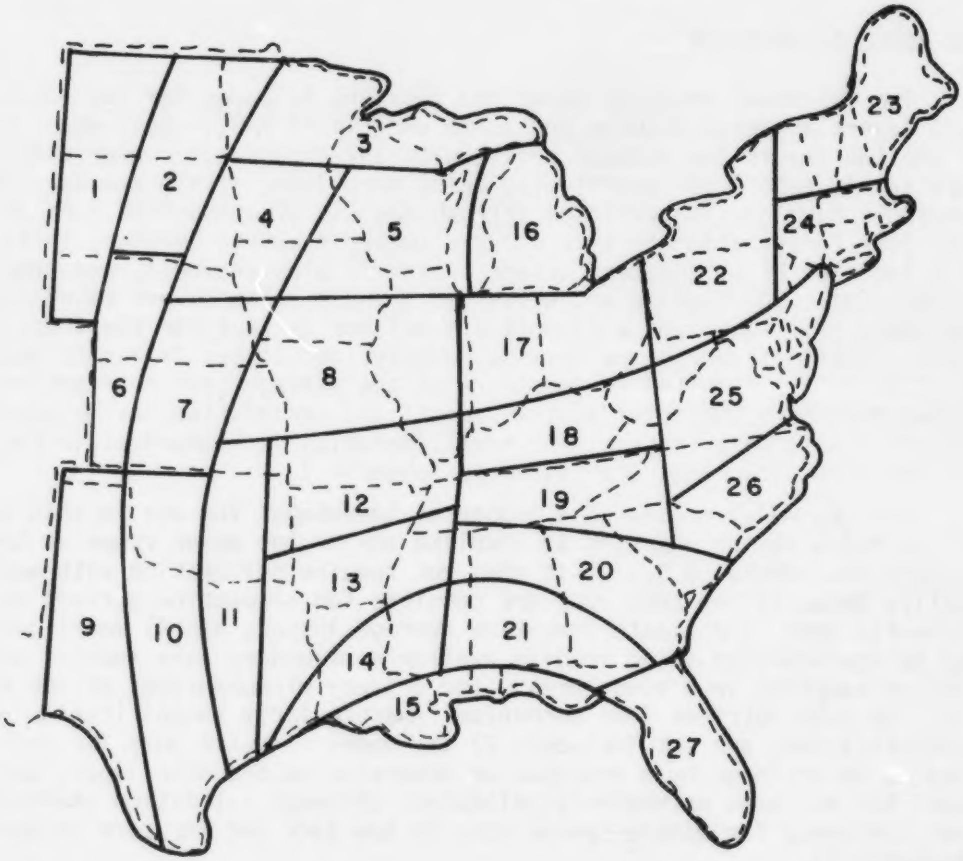


Figure A-2. Climatic Regions for Model Runs.

SECTION 2

USE OF THE CNS MODEL TO DEVELOP PREDICTIVE EQUATIONS FOR WATER LOSSES AND NUTRIENT CONCENTRATIONS

CNS MODEL DESCRIPTION

The CNS model computes water and nutrient balances for two adjacent soil layers at depth 0-10 cm and 10-30 cm (Figure A-3). Soil water contents of the two layers are updated daily, with any excess water over field capacity in each layer percolating below that layer within one day. Direct runoff on each day is predicted through the use of a modified form of the U.S. Soil Conservation Service's curve number equation (Mockus, 1972), and is a function of soil water content, rainfall plus snowmelt, and crop curve number (CN). Solid-phase and dissolved N and P balances are maintained for the upper soil layer and a dissolved N balance is kept for the lower soil layer. Nutrient levels are updated monthly, and losses in runoff and percolation are computed as functions of the average soil nutrient contents during the month and total monthly runoff and percolation, as obtained from the daily soil water model. The model operation is summarized in Figure A-4, and the model equations are listed in Appendix I.

The CNS model presented a number of advantages for use in this study: 1) the model may be adjusted to simulate any of the major crops in the eastern and central U.S.; 2) it does not require calibration with water quality data; 3) low cost runs are possible for simulation periods sufficiently long to estimate long-term average losses; and 4) model parameters may be approximated using readily available secondary data sources and/or by limited sampling in a study area. The primary disadvantages of the model are: 1) some nutrient loss mechanisms (particularly ammonification and dentrification) are not included; 2) the model is valid only for soils not limited in drainage by a fragipan or otherwise impermeable layer; and 3) the model has not been extensively validated, although validation studies have been performed for manure-spread corn in New York and for corn in Georgia (Appendix I).

The limitations of the CNS model also indicate limitations in the nutrient loss predictive equations derived from the model results. Specifically, the predictive equations are only applicable to soils that are unrestricted in drainage, and ammonification and denitrification losses must be subtracted from fertilizer or manure nitrogen inputs before applying the predictive equations. The final problem is most relevant if the equations are used to generate exact loading estimates from an existing or proposed cropping scheme. In this case, field monitoring or water quality sampling may be necessary in order to support the accuracy of the predictive

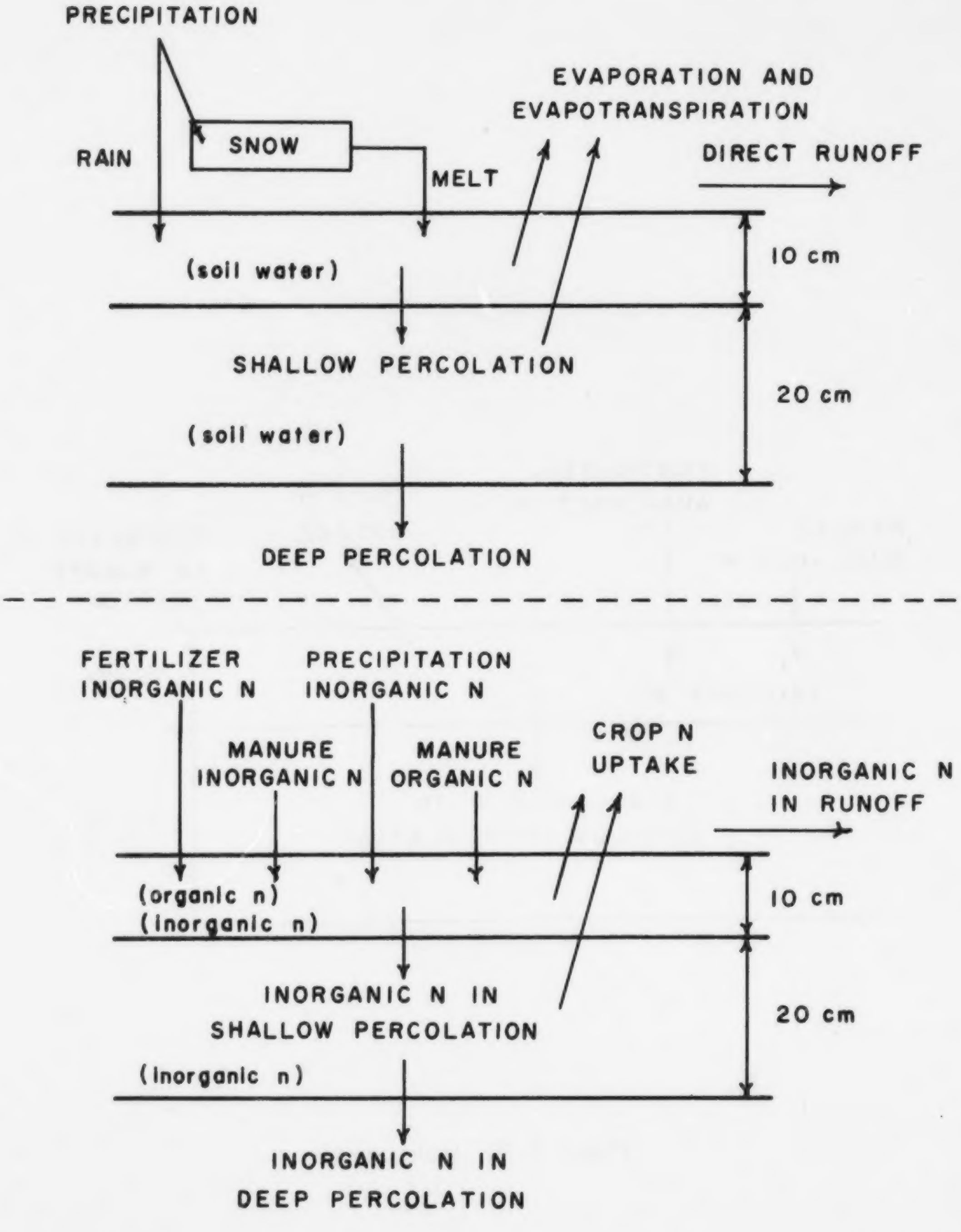


Figure A-3. Soil water and nutrient balances in the CNS model.

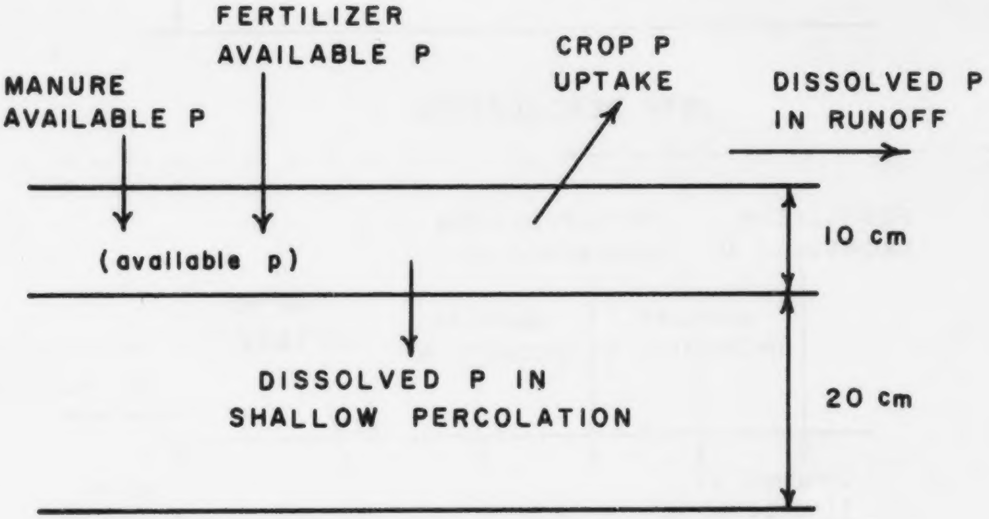
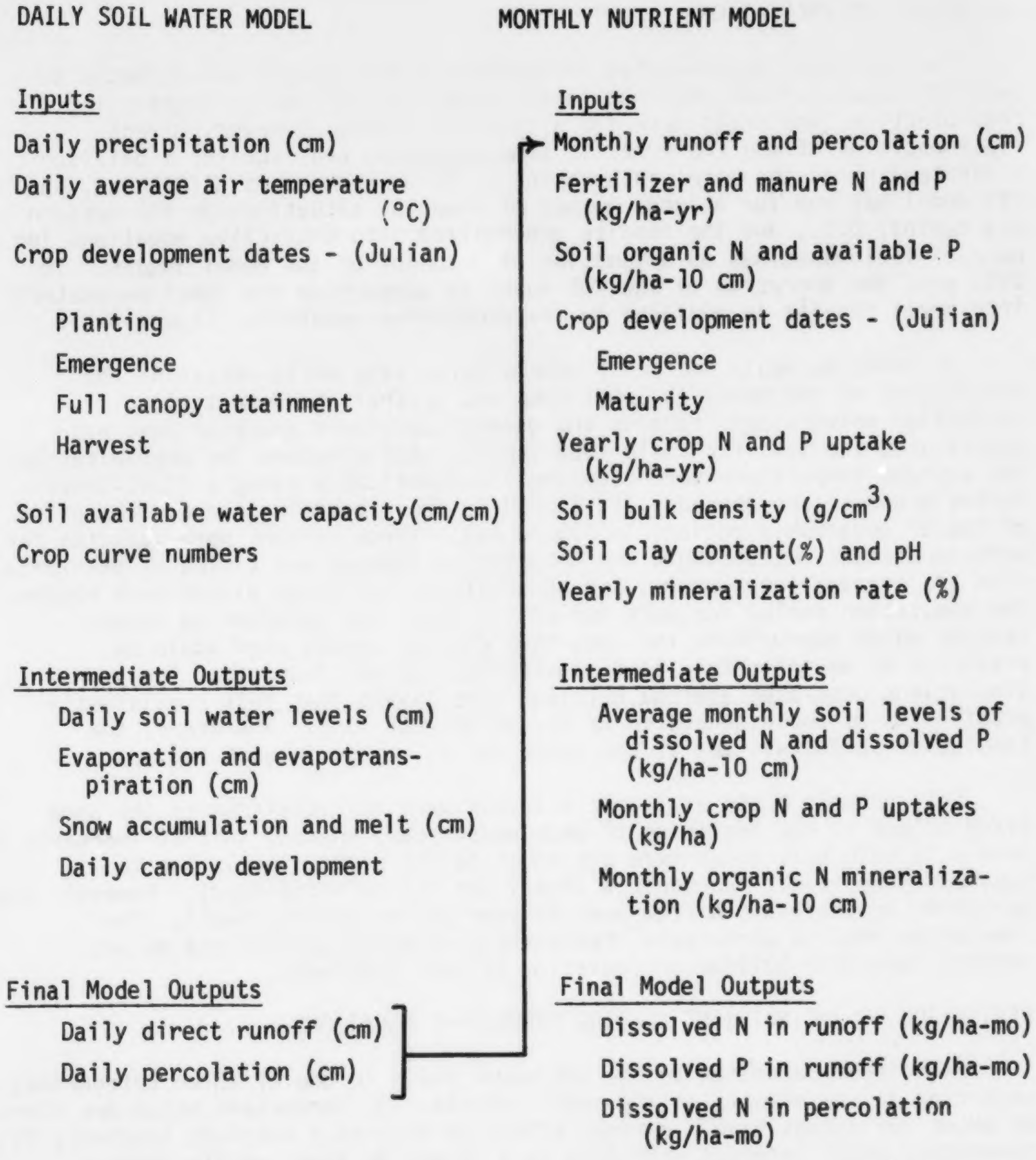


Figure A-3. (Continued)



DAILY SOIL WATER MODEL

Inputs

- Daily precipitation (cm)
- Daily average air temperature (°C)
- Crop development dates - (Julian)
  - Planting
  - Emergence
  - Full canopy attainment
  - Harvest
- Soil available water capacity(cm/cm)
- Crop curve numbers

Intermediate Outputs

- Daily soil water levels (cm)
- Evaporation and evapotranspiration (cm)
- Snow accumulation and melt (cm)
- Daily canopy development

Final Model Outputs

- Daily direct runoff (cm)
- Daily percolation (cm)

MONTHLY NUTRIENT MODEL

Inputs

- Monthly runoff and percolation (cm)
- Fertilizer and manure N and P (kg/ha-yr)
- Soil organic N and available P (kg/ha-10 cm)
- Crop development dates - (Julian)
  - Emergence
  - Maturity
- Yearly crop N and P uptake (kg/ha-yr)
- Soil bulk density (g/cm^3)
- Soil clay content(%) and pH
- Yearly mineralization rate (%)

Intermediate Outputs

- Average monthly soil levels of dissolved N and dissolved P (kg/ha-10 cm)
- Monthly crop N and P uptakes (kg/ha)
- Monthly organic N mineralization (kg/ha-10 cm)

Final Model Outputs

- Dissolved N in runoff (kg/ha-mo)
- Dissolved P in runoff (kg/ha-mo)
- Dissolved N in percolation (kg/ha-mo)

Figure A-4. Flowchart of the CNS model operation.

equations. However, if the equations are to be used to judge the relative effectiveness of alternative measures for reducing pollutant losses, particularly in an economic analysis, this sampling may not be needed.

CNS MODEL IMPLEMENTATION

The CNS model as presented in Appendix I may be utilized directly to generate edge-of-field nutrient losses given the appropriate meteorologic, crop practice, and soils data for a specific field. However, direct implementation of the CNS model is time-consuming and requires a detailed understanding of the model interactions. To overcome this difficulty, **the CNS model was run for a large number of cropping situations in the eastern and central U.S., and the results generalized into predictive equations for edge-of-field loadings as a function of a subset of the model inputs. In this way, the operation of the CNS model in converting the input parameters into model results is replaced by the predictive equations** (Figure A-5).

In order to apply the model over a large area while retaining the sensitivity of the model to local crop and weather characteristics, randomized meteorologic records and generalized field practice data was substituted for specific field data inputs. Daily values for precipitation and average temperature were generated stochastically using a first-order Markov process (see Appendix II) fitted to the meteorologic characteristics of the 27 geographic regions in Figure A-2. These regions were selected for both consistent meteorologic characteristics (amount and timing of precipitation and average temperature) and agricultural practices within each region. The simulation period for each run of the model was selected to assure results which approximate the long-term average losses that would be predicted by an infinitely long simulation. It was found that ten-year simulations generated average nutrient loss levels that fell consistently within + 5% of those generated by 25- or 50-year runs. Therefore, the simulation period was set at ten years for all crops in each region.

Soil organic N and available P levels were reinitialized to the same fixed values at the beginning of each model year, whereas initial inorganic N levels in both soil zones were set equal to the ending levels for the previous year (i.e., inorganic N levels are not reinitialized). However, the carryover of inorganic N from year to year was relatively small. The simulation results aproximate steady-state cropping systems and do not reflect long-term buildup or depletion of soil nutrients.

DERIVATION OF THE NUTRIENT LOADING PREDICTIVE EQUATIONS

Each input parameter to the CNS model falls in one of three categories, according to its effects on the model outputs: 1) parameters which are fixed or whose variations have a minimal effect on predicted nutrient loadings; 2) parameters which interact according to a linear or other easily defined function with model outputs; and 3) parameters which affect loading estimates in a non-uniform (but significant) fashion. For example, the concentration of dissolved N in precipitation is fixed for any area, while fertilization rates vary substantially from one cropping system to another, and directly affect estimated dissolved N or P loss in runoff and percolation.

Figure A-5. Relations of the CNS model to the predictive equations.

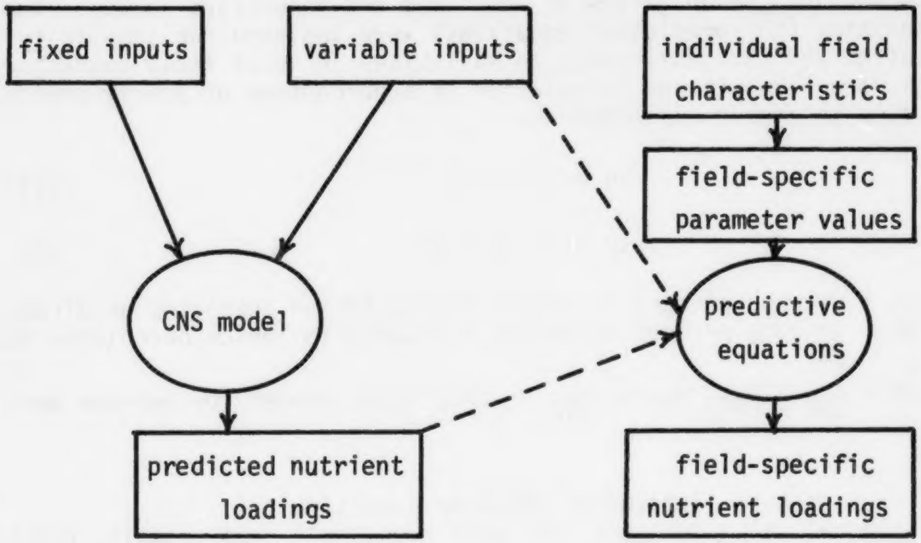

fixed inputs
variable inputs
individual field characteristics
field-specific parameter values
CNS model
predictive equations
predicted nutrient loadings
field-specific nutrient loadings

Table A-1 classifies the various model inputs according to this scheme, for any crop and geographic region. The fixed parameters are not included in the predictive equations, because they are assumed not to vary significantly between different management options for a specific crop. The nonuniform parameters cannot be related mathematically to the model results, but have a substantial effect on the levels of nutrient losses. Consequently, predictive equations must be derived for a range of each of these nonuniform parameters in each geographic region in order to capture their effects on edge-of-field loadings. This is reflected in the organization of Appendix III, where, for each crop and region, equation coefficients are presented for all combinations of tillage dates (spring or fall), fertilizer application dates (spring or fall), soil hydrologic group (A, B, C, or D), and a range of soil available water capacities (.05, .10, .15, and .20 cm of water/cm of soil).

The remaining input parameters may be related directly to the model results for any chosen values of the fixed and nonuniform inputs. These relationships (the predictive equations) were designed for simplicity in application and for sensitivity to variations in local field characteristics. Average annual runoff and percolation as a percentage of yearly precipitation is related to crop curve number by:

$$\%R = a\,\hat{CN} + b \tag{1}$$

$$\%P = a'\,\hat{CN} + b' \tag{2}$$

where $\%R$ = average percent of annual precipitation appearing as direct runoff
$\%P$ = average percent of annual precipitation which percolates below 30 cm.
$\hat{CN} = \frac{100}{100 - CN_{II}}$ where CN_{II} = crop curve number for average soil moisture (antecedent moisture condition II)
a, b, a', b' = constants for each crop, soil, and cropping practice

Runoff and percolation percentages may be multiplied by the average annual precipitation at a specific location to obtain average annual runoff and percolation,

$$R = \frac{(\%R)\,(\overline{Pr})}{100} \tag{3}$$

$$P = \frac{(\%P)\,(\overline{Pr})}{100} \tag{4}$$

where R = average annual direct runoff (cm)
P = average annual percolation (cm)
$\overline{Pr}$ = average annual precipitation (cm)

TABLE A-1. CLASSIFICATION OF CNS MODEL INPUTS ACCORDING TO THEIR INFLUENCE ON PREDICTED NUTRIENT LOADINGS

FIXED INPUT PARAMETERS:

- Meteorologic data
- Dates of crop development
- Crop N and P uptakes
- Mineralization rates
- Dissolved N concentration in precipitation

PARAMETERS WHICH VARY MODEL OUTPUTS CONTINUOUSLY:

- Crop curve number
- Fertilization rates of N and P
- Soil organic N and available P contents
- Soil P adsorption capacity
- Soil bulk density

PARAMETERS WHICH VARY MODEL OUTPUTS NON-UNIFORMLY:

- Soil available water capacity
- Soil hydrologic group
- Timing of fertilizer application
- Timing of tillage operations

The coefficient of determination (r^2) between %R and $\hat{C}N$ and between %P and $\hat{C}N$ was greater than 0.99 for all modelled crops and regions.

Similarly, the following predictive equations approximate the relationship between the CNS model input parameters and average annual dissolved N concentrations in runoff and percolation and average annual dissolved P concentration in runoff.

$$K_{RN} = a_0 + a_1\hat{C}N + a_2F_N + a_3S_N + a_4F_N\hat{C}N + a_5S_N\hat{C}N \qquad (5)$$

$$K_{PN} = b_0 + b_1\hat{C}N + b_2F_N + b_3S_N + b_4F_N\hat{C}N + b_5S_N\hat{C}N \qquad (6)$$

$$K_{RP} = \gamma_P(c_0 + c_1\hat{C}N + c_2F_P + c_3S_P + c_4F_P\hat{C}N + c_5S_P\hat{C}N) \qquad (7)$$

where K_{RN} = average concentration of dissolved N in runoff (mg/ℓ)

K_{PN} = average concentration of dissolved N in percolation (mg/ℓ)

K_{RP} = average concentration of dissolved P in runoff (μg/ℓ)

F_N = annual fertilizer and manure inorganic N input (10^2 kg/ha-yr)

S_N = soil organic N in the surface 10 cm (10^3 kg/ha)

γ_P = adjustment factor for soil P adsorption capacity (dmless)

F_P = annual fertilizer and manure available P input (kg/ha-yr)

S_P = soil available P in the surface 10 cm (kg/ha)

a_i, b_i, c_i = constants for each crop, soil, and cropping practice

The choice of units for F_N, F_P, S_N, and S_P are such that the constants a_i, b_i, and c_i may have the same approximate order of magnitude, for ease in presentation in Appendix III. The coefficients of determination (r^2) between K_{RN} and the right-hand terms of equation 5 and between K_{PN} and the right-hand terms of equation 6 are greater than 0.97 for all crops and regions modelled, and the multiple correlation coefficient for equation 7 is always greater than 0.99.

The soil P adsorption capacity adjustment factor γ_P is a fraction of soil bulk density ρ and the phosphorus adsorption coefficient β, which in turn is a function of soil pH and clay content:

$$\beta = 5.1 + 2.2(\%C) + 26.4(pH - 6.0)^2 \qquad (8)$$

where β = soil adsorption coefficient for available P $(\frac{mg/kg}{mg/\ell})$

%C = percent clay content (soil particles < .002 mm) in the surface 10 cm of soil

pH = average pH of surface 10 cm of soil

In generating values for the coefficients in equation 7, the CNS model was provided with reference values for soil bulk density ρ of 1.3 g/cm^3, clay content of 15%, and a pH of 7.0, yielding a value for β of 65 $\frac{mg/kg}{mg/\ell}$. The factor γ_P captures the effect on dissolved P concentrations in runoff of differences in ρ and β from these reference values:

$$\gamma_P = \frac{(1.3)\ (65)}{\rho\ \ \beta} = \frac{84.5}{\rho\ \beta} \qquad (9)$$

Methods for determining values of $\hat{CN}$, F_N, F_P, S_N, S_P, and γ_P and for selecting the appropriate equation coefficients from Appendix III based on field characteristics are detailed in Section 3.

DATA USED IN THE CNS SIMULATIONS

This section details the data acquisition methods for all runs performed with the CNS model. The appropriate methods for selecting values for each input parameter to the CNS model are dependent on the relationship between that input parameter and the model results. Referring back to Table A-1, the procedures for data acquisition are different for the fixed, continuous, and nonuniform input parameters.

Fixed Input Parameters

The fixed parameters in this application of the CNS model do not vary between simulations of different management options, although there will be differences in the parameter values among geographic regions.

Meteorologic Data--

The meteorologic models in Appendix II require input data for average precipitation and number of days with precipitation by month, and average summer and annual air temperatures. Data was obtained from a single source (National Oceanic and Atmospheric Administration, 1974), which summarizes the meteorologic characteristics of a number of weather stations in each of the fifty states. For each geographic region in Figure A-2, one station was selected to provide precipitation and temperature data for that region (Tables A-2 and A-3).

TABLE A-2. AVERAGE PRECIPITATION(cm) AND NUMBER OF DAYS W/ PRECIPITATION BY MO. FOR EACH STUDY REGION

Region	Weather Station	Month												
		J	F	M	A	M	J	J	A	S	O	N	D	Total
1	Rapid City, S.D.	1.2	0.8	2.7	5.1	7.7	8.5	5.2	4.0	3.0	2.9	1.4	0.9	43.4
	# days	7	6	9	8	12	13	9	8	6	5	5	5	93
2	Fargo, N.D.	1.5	1.7	2.3	4.8	5.5	7.7	5.9	6.9	4.4	3.2	2.2	1.5	47.6
	# days	10	8	9	8	11	11	10	9	9	6	7	8	106
3	Duluth, Minn.	2.9	2.4	4.1	6.0	8.4	10.8	9.0	9.7	7.3	5.5	4.5	2.9	73.6
	# days	12	10	11	11	13	13	11	11	11	9	11	13	135
4	Sioux Falls, S.D.	1.8	1.9	3.4	6.0	8.6	10.8	7.6	8.3	7.4	3.7	2.8	1.7	64.1
	# days	5	6	9	8	10	11	10	10	7	6	5	6	93
5	LaCrosse, Wisc.	3.1	2.8	4.7	5.9	8.3	9.8	8.2	8.4	9.7	4.9	4.6	3.1	73.5
	# days	8	6	12	9	12	11	12	9	8	7	9	9	112
6	N. Platte, Neb.	1.0	0.9	2.3	5.2	6.8	7.4	6.1	5.4	4.4	2.6	1.4	1.0	44.6
	# days	6	5	6	8	9	9	8	9	4	5	6	4	79
7	Concordia, Kans.	1.5	2.2	3.4	5.7	9.2	10.7	8.6	8.1	6.2	4.4	2.9	1.5	64.5
	# days	5	5	7	9	11	10	8	9	7	6	5	4	86
8	Burlington, Iowa	4.2	3.5	6.9	8.7	10.2	12.7	8.6	9.2	8.1	6.9	4.8	4.1	87.9
	# days	7	7	10	11	12	11	9	8	9	7	7	7	104
9	Lubbock, Tex.	1.7	1.4	1.9	2.9	8.1	6.4	5.1	4.3	6.0	5.1	1.4	1.7	45.9
	# days	4	4	4	4	8	7	8	6	5	5	3	3	60
10	Abilene, Tex.	2.2	2.8	2.6	5.8	11.0	6.8	5.8	3.7	5.3	7.2	2.8	3.2	59.2
	# days	5	5	4	7	8	6	5	5	6	5	5	4	65
11	Austin, Tex.	6.0	6.6	5.4	9.0	9.4	8.2	5.5	4.9	8.7	7.2	5.4	6.4	82.8
	# days	8	9	7	7	8	6	4	5	7	6	7	7	81

TABLE A-2. (Continued)

Region	Weather Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
12	Springfield, Mo.	5.0	5.4	7.2	10.4	13.4	12.8	9.9	8.4	9.8	9.6	7.0	5.6	104.3
	# days	8	8	10	10	11	10	9	9	8	7	8	8	106
13	Texarkana, Ark.	12.3	10.2	12.0	13.5	12.4	9.9	9.8	7.8	6.9	7.6	11.0	11.6	124.9
	# days	10	10	11	10	9	7	7	8	7	5	7	9	98
14	Jackson, Miss.	12.9	12.9	15.8	12.2	10.4	9.4	11.7	8.3	5.3	5.5	10.3	14.2	129.2
	# days	11	11	10	9	9	9	11	7	7	5	8	10	107
15	New Orleans, La.	12.1	10.6	16.7	13.8	13.8	14.1	18.0	16.3	14.8	9.3	10.2	11.6	161.4
	# days	10	9	9	7	9	13	15	14	10	6	8	10	120
16	Grand Rapids, Mich.	4.9	4.4	5.8	7.5	8.8	8.4	6.9	6.9	7.6	6.6	6.3	5.2	79.2
	# days	12	12	16	13	8	7	8	11	11	9	14	17	137
17	Fort Wayne, Ind.	6.5	4.5	8.0	8.3	8.7	9.0	8.3	7.1	7.8	6.7	6.1	5.7	86.8
	# days	14	11	13	13	12	11	10	8	7	8	10	12	129
18	Lexington, Ky.	11.4	8.9	11.3	9.6	9.0	10.7	10.8	8.6	7.2	6.2	8.0	9.3	111.0
	# days	13	12	13	12	12	12	11	10	8	8	10	12	133
19	Knoxville, Tenn.	11.5	12.0	12.3	9.2	9.1	8.8	12.0	8.7	6.4	6.7	8.0	10.8	115.6
	# days	13	12	13	11	12	12	12	11	8	7	9	12	132
20	Atlanta, Ga.	11.3	11.5	13.6	11.4	8.0	9.7	12.0	9.1	8.3	6.2	7.5	11.1	119.7
	# days	11	10	12	9	9	10	12	9	7	6	8	10	115
21	Montgomery, Ala.	11.7	12.0	16.5	12.2	8.8	11.9	14.6	12.1	8.9	6.0	10.0	11.5	136.3
	# days	11	10	10	8	9	11	12	11	8	6	7	10	113
22	Binghamton, N.Y.	6.4	5.5	7.3	7.5	8.9	9.8	9.4	9.1	7.5	7.8	6.4	6.5	92.0
	# days	17	15	16	14	13	11	10	11	9	11	14	18	161

TABLE A-2. (continued)

Region	Weather Station	Month												
		J	F	M	A	M	J	J	A	S	O	N	D	Total
23	Portland, Me.	11.1	9.7	11.0	9.5	8.7	8.1	7.3	6.1	8.9	8.1	10.6	9.8	108.8
	# days	11	10	11	12	13	11	9	10	8	9	12	11	125
24	Albany, NY	6.3	5.6	6.9	7.0	8.8	8.3	8.9	7.8	9.1	7.0	6.9	6.6	89.1
	# days	13	11	12	12	13	11	11	10	9	8	12	12	133
25	Baltimore, Md.	9.3	7.6	9.2	9.4	10.2	8.9	10.0	11.1	8.8	8.6	7.5	7.5	108.2
	# days	12	8	13	11	11	10	6	10	9	7	9	9	115
26	Wilmington, NC	7.2	8.7	10.2	7.3	8.9	10.8	19.5	17.4	16.0	7.6	7.8	8.7	130.3
	# days	10	10	10	8	9	10	14	12	9	7	7	9	115
27	Tampa, Fla.	5.4	7.2	9.5	7.2	7.2	18.5	21.9	20.9	17.5	7.1	3.7	4.8	131.0
	# days	6	7	7	5	6	12	17	17	13	8	5	6	108

TABLE A-3. AVERAGE JULY AND AVERAGE ANNUAL TEMPERATURE (^{o}C) FOR EACH STUDY REGION

Region	Average Temperature	
	July	Annual
1	22.4	8.2
2	21.8	4.0
3	18.6	2.8
4	23.8	6.9
5	23.3	7.1
6	24.3	9.9
7	26.7	12.2
8	24.8	10.3
9	26.4	15.2
10	28.4	17.7
11	29.3	19.8
12	26.0	13.4
13	28.1	17.7
14	27.8	18.4
15	28.6	20.9
16	22.4	8.9
17	23.1	9.9
18	24.8	12.9
19	25.8	15.2
20	26.1	16.6
21	27.3	18.4
22	20.2	7.8
23	20.1	7.2
24	22.3	8.6
25	24.9	13.2
26	26.7	17.8
27	27.8	22.0

Dates of Crop Development--

Normal ranges of the dates of planting and harvest by state for each crop were obtained from published data (U.S. Department of Agriculture, 1972). The dates of planting and harvest for all years of the simulation in each region were fixed at the mean dates for the states contained in each region (Table A-4). Hay is grown continuously throughout the year, and nutrient uptake was assumed to occur from 30 days before first cutting until the last cutting in the fall. Dates of crop emergence, full canopy attainment, and crop maturity were determined by adding a fixed crop development period for each crop to the date of planting. For example, crop emergence for corn in each region occurs approximately 14 days after planting in that region, and full canopy is reached 75 days after planting. Further crop development data is given in Table A-5. The variation in time to maturity for corn by region is due to the use of shorter-season hybirds in the northern U.S.

Crop Nutrient Uptakes--

The CNS model computes dissolved N and P uptakes by month as a function of total yearly crop uptake and a crop development curve fitted to the dates of crop development (see Appendix I). Average crop yields by region were obtained from a recent agricultural census (U.S. Department of Agriculture, 1977) and were combined with crop nutrient contents (Martin and Leonard, 1967) to determine the yearly nutrient uptakes presented in Table A-6. For corn, the yields for silage were used to determine crop uptakes. If corn is harvested for grain, the N and P remaining in the stover will return to the field in both organic and inorganic forms. Consequently, all N and P remaining on the field in crop residues are to be added to the amount of these nutrients applied in fertilizer or manure in each year. A substantial fraction of the nitrogen needs of leguminous crops is met through fixation of atmospheric N. It was assumed in the operation of the model that a leguminous crop will utilize any available inorganic N before fixing atmospheric N.

Mineralization Rates--

The rate of nitrogen mineralization from organic to inorganic N is roughly proportional to average temperature, and ranges from 2% to 4% per year (Brady, 1974). Therefore, mineralization rates were chosen for each region which reflect the average annual temperature of the station representing that region. The rates used in the CNS model runs are summarized in Table A-7.

Dissolved N in Precipitation--

The amount of dissolved N in precipitation, although small, will affect the concentrations of N loss in runoff and percolation for crops which are fertilized at low levels. The total yearly loadings shown in Figure A-6 (McElroy, et al., 1976) were divided by average annual precipitation in each region to determine the average concentration of dissolved N in precipitation in each region. The dissolved N input from precipitation in each month of the simulation was then equal to the total precipitation for the month times the average concentration for the region.

TABLE A-4. DATES OF PLANTING AND HARVEST FOR MAJOR CROPS IN EACH REGION

REGION	CROP							
	Corn		Hay		Soybeans		Winter Wheat	
	Plant	Harvest	Begin Harvest	End Harvest	Plant	Harvest	Plant	Harvest
1	6/1	11/1	6/10	9/20	6/1	10/15	9/15	8/1
2	6/1	11/1	6/10	9/20	6/1	10/15	9/15	8/1
3	5/25	11/1	6/5	9/5	6/1	10/20	-	-
4	5/20	11/1	6/1	9/1	6/1	10/15	-	-
5	5/20	11/5	6/5	9/15	6/1	10/20	-	-
6	5/10	11/1	5/20	10/1	6/5	10/20	9/25	7/1
7	5/10	11/1	5/20	10/1	6/5	10/20	9/25	7/1
8	5/15	11/1	5/20	9/15	6/1	10/10	10/15	7/1
9	4/15	10/1	-	-	6/10	11/1	10/1	6/10
10	4/15	10/1	-	-	6/10	11/1	10/1	6/10
11	4/15	10/1	-	-	6/10	11/1	10/1	6/15
12	5/5	10/20	5/15	10/1	6/1	11/1	10/15	6/20
13	4/15	10/5	-	-	6/1	11/1	10/15	6/10
14	4/15	10/10	-	-	6/1	10/25	-	-
15	4/20	10/10	-	-	6/5	10/25	-	-
16	5/25	11/1	6/1	10/15	6/1	10/15	10/1	7/25
17	5/25	11/5	5/20	9/20	6/1	10/15	10/5	7/15
18	6/1	10/10	5/15	9/15	6/5	10/15	10/10	7/15
19	5/15	10/25	5/1	10/1	6/1	11/1	10/20	6/25
20	5/1	10/15	-	-	6/5	10/25	10/20	6/10
21	5/1	10/15	-	-	6/10	10/15	-	-
22	5/25	10/20	5/25	10/1	-	-	9/20	8/1
23	6/1	11/1	6/5	9/10	-	-	-	-
24	6/1	11/1	6/1	9/20	-	-	-	-
25	5/20	10/20	5/1	10/20	5/20	11/5	10/25	7/1
26	5/5	10/20	5/25	10/1	6/1	11/15	10/10	7/1
27	4/1	9/15	-	-	6/1	10/15	-	-

TABLE A-5. AVERAGE TIME FROM PLAINTING TO CROP EMERGENCE, FULL CANOPY DEVELOPMENT, AND MATURITY FOR MAJOR CROPS IN THE EASTERN AND CENTRAL U.S. (DAYS)

CROP	EMERGENCE[1]	FULL CANOPY	MATURITY
Corn	14	75[2]	129 (north)[1]
			154 (south)[1]
Soybeans	14	100[3]	130[3]
Hay	-	-	full season
Winter Wheat	14	100	full season

1) Martin and Leonard, 1967

2) Hanway, 1962

3) Hill, 1975

TABLE A-6. AVERAGE ANNUAL NITROGEN (N) AND PHOSPHORUS (P) UPTAKES (KG/HA-YR) FOR MAJOR CROPS IN EACH STUDY REGION

REGION	CROP							
	Corn		Hay-Alfalfa		Soybeans		Winter Wheat	
	N	P	N	P	N	P	N	P
1	38	9	80	7	70	7	38	8
2	38	9	80	7	70	7	38	8
3	68	16	150	12	75	8	-	-
4	68	16	150	12	80	8	-	-
5	83	20	160	13	95	10	-	-
6	75	18	150	12	70	8	38	8
7	75	18	150	12	70	8	38	8
8	90	22	165	14	85	9	40	8
9	112	27	-	-	90	10	25	5
10	112	27	-	-	90	10	25	5
11	105	25	-	-	85	9	28	6
12	75	18	-	-	75	8	40	8
13	83	20	-	-	80	9	34	7
14	90	22	-	-	80	8	-	-
15	83	20	-	-	80	9	-	-
16	83	20	145	12	80	9	48	10
17	105	25	160	13	115	12	50	10
18	112	27	-	-	90	10	40	8
19	105	25	-	-	80	8	40	8
20	90	22	-	-	80	9	32	6
21	83	20	-	-	80	9	-	-
22	98	23	150	12	-	-	45	9
23	98	23	125	11	-	-	-	-
24	105	25	145	12	-	-	-	-
25	105	25	-	-	80	8	40	8
26	98	23	-	-	75	8	38	8
27	83	20	-	-	90	10	-	-

TABLE A-7. AVERAGE MINERALIZATION RATE (%/YEAR) FOR SOIL ORGANIC N USED IN CNS MODEL RUNS BY REGION

REGION	RATE	REGION	RATE	REGION	RATE
1	2.0	10	3.5	19	3.0
2	1.5	11	4.0	20	3.0
3	1.5	12	2.5	21	3.5
4	2.0	13	3.5	22	1.5
5	2.0	14	3.5	23	1.5
6	2.0	15	4.0	24	2.0
7	2.5	16	2.0	25	2.5
8	2.5	17	2.0	26	3.5
9	3.0	18	2.5	27	4.5

Continuous Input Parameters

The parameters in this group may assume continuous values and will vary model outputs in a continuous and well-defined fashion (the predictive equations). For each combination of the fixed and nonuniform input parameters, the CNS model was replicated for a number of combinations of the continuous inputs sufficient to determine the predictive equations. Because the predictive equations varied uniformly with the independent variables, it was necessary to repeat the model runs for each cropping situation for only two values of curve number (CN), fertilization rate (F_N, F_P), and soil fertility level (S_N, S_P) to determine the predictive equation coefficients. Soil P adsorption capacity and bulk density were not varied between runs, since their effects on dissolved P loss in runoff are inferred directly from the model equations in Appendix I. The effect of variations in these factors on dissolved P loadings is contained in the variable γ_P, as computed by equation 9.

In summary, for each cropping alternative in each region, the CNS model was run eight times, representing all combinations of two curve numbers, two levels of fertilization, and two soil fertility levels. Curve numbers were set at $CN_{II} = 60$ or $CN_{II} = 90$, soil organic N was initialized at 1000 kg/ha-10 cm or 10,000 kg/ha-10 cm at the beginning of each model year, and soil available P was initialized at 10 kg/ha or 200 kg/ha at the beginning of each model year. Annual fertilizer N and P inputs were set at 50% or at 200% of the normal fertilization rate for each crop. For corn, this range translates to 50 kg/ha-yr or 200 kg/ha-yr of inorganic N in all regions, and 10 kg/ha-yr or 70 kg/ha-yr of available P in all regions. Hay fertilization rates were 10 kg/ha-yr or 70 kg/ha-yr for both inorganic N and available P. Soybean fertilization rates were 0 kg/ha-yr or 30 kg/ha-yr for incorganic N and 10 kg/ha-yr or 50 kg/ha-yr for available P.

Non-uniform Input Parameters

As mentioned previously, the non-uniform parameters have a substantial effect on the levels of predicted nutrient loadings, but cannot be related directly to the model results. Soil hydrologic group is a categorical variable (A, B, C, or D), and determines the magnitude of direct runoff under fallow conditions, independent of crop curve number. Soil water capacity, although a continuous variable, exerts a nonuniform effect on nutrient loss. Discrete values for soil water capacity of .05, .10, .15, and .20 cm of water/cm of soil were modelled for all combinations of the continuous and other nonuniform variables.

Timing of tillage and fertilizer application were both related to the times of planting and harvest in each region. Fall plowing was assumed to occur two weeks after crop harvest, and spring plowing occured one month before planting. Fertilizer N and P were added to the nutrient budget in the month after harvest for fall fertilization and in the month previous to planting for spring fertilization. Hay was assumed to be fertilized in the month previous to first cutting. No-tillage was modelled as continuous cover (no bare-soil periods).

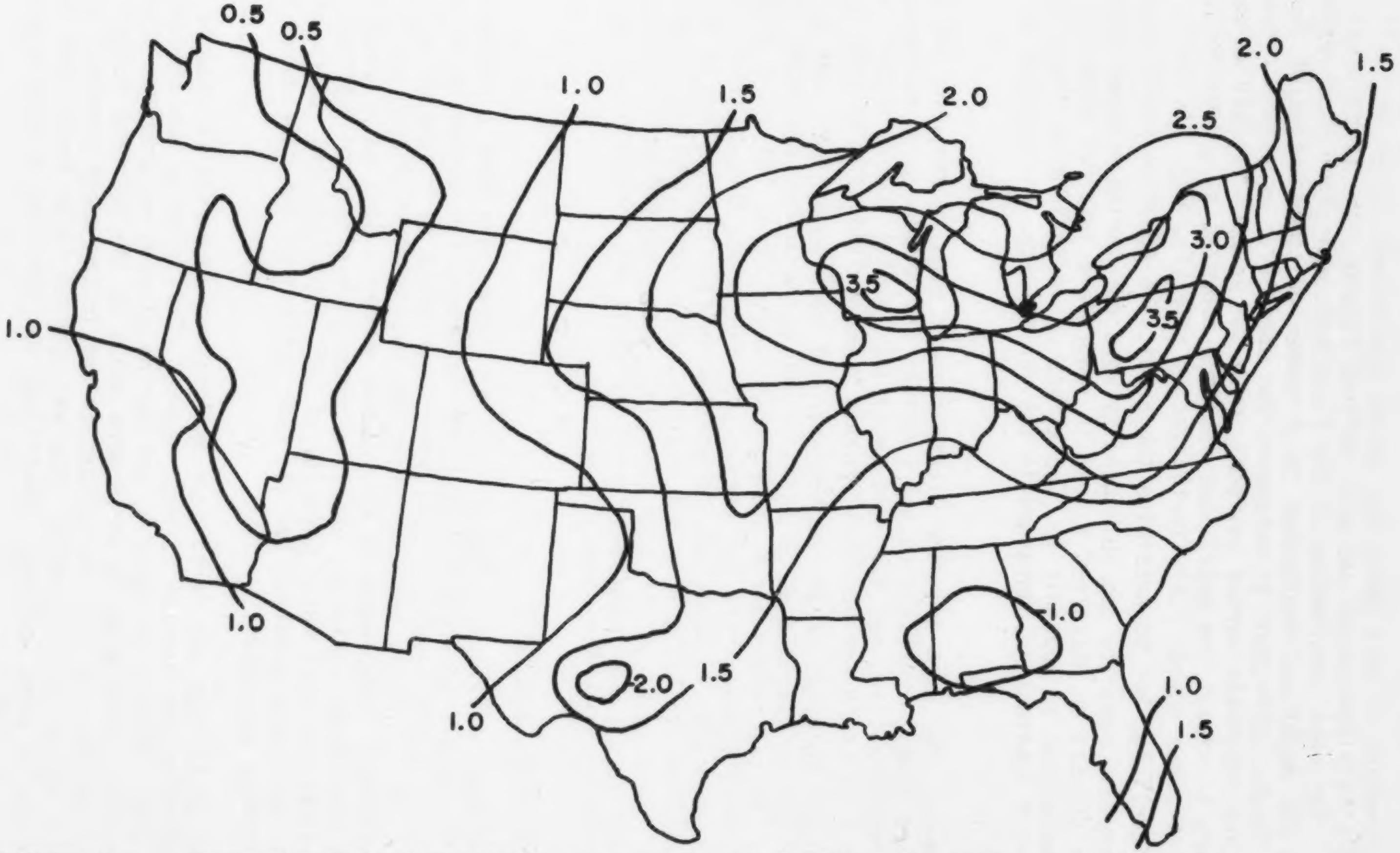


FIGURE A-6. AVERAGE ANNUAL NITROGEN (Kg/Ha) IN PRECIPITATION. (SOURCE: J.H. CRAVER, PROVIDED IN McELROY ET AL., 1976)

SUMMARY

The CNS model was used to estimate edge-of-field loadings of dissolved N and P for a number of combinations of crops, soils, and field practices. Loading estimates were condensed into predictive equations for water and nutrient loss as a function of soil and crop characteristics. The coefficients for the predictive equations for each modelled crop are presented in Appendix III. Table A-8 summarizes the various crops, soils, and field practices modelled.

TABLE A-8. CROPS AND PRACTICES SIMULATED WITH THE CNS MODEL

CROP	TIME OF PLOWING	TIME OF FERTILIZATION	GEOGRAPHIC REGIONS
Corn	Spring	Spring	all
		Fall	all
	Fall	Spring	all
		Fall	all
	Reduced Tillage	Spring	all
		Fall	all
Hay	No Tillage	Spring	1-8, 12, 16-19, 22-26
Soybeans	Spring	Spring	1-21, 25-27
		Fall	1-21, 25-27
	Fall	Spring	1-21, 25-27
		Fall	1-21, 25-27
	Reduced Tillage	Spring	1-21, 25-27
		Fall	1-21, 25-27
Corn with Winter Wheat	No Tillage	Spring	1, 2, 6-13, 16-20, 22, 25, 26
		Fall	1, 2, 6-13, 16-20, 22, 25, 26

SECTION 3

A GENERAL METHODOLOGY FOR ESTIMATING NONPOINT SOURCE NUTRIENT LOADINGS

In this section, the predictive equations derived in Section 2 for runoff, percolation, and dissolved nutrient loadings from cropland are combined with the USLE to produce a methodology for predicting average annual edge-of-field water and nutrient losses for several major field crops in the eastern and central U.S. Methods are also presented for obtaining approximate estimates of average nutrient delivery from edge-of-field to surface waters.

Three objectives may be met through application of the methodology presented in this section:

1. **Dissolved and solid-phase pollutant loading may be estimated for a specific field, given certain crop characteristics,**

2. **The effectiveness of a specific management practice in reducing or eliminating pollutant loading as compared to base conditions (say, the present cropping system) may be evaluated, and**

3. **Two or more control practices may be ranked according to their effectiveness in reducing the loading of each pollutant.**

Each of these objectives requires the computation of pollutant loading based on particular field characteristics for each alternative practice. Table A-9 summarizes the required data, predictive equations, and the resulting pollutant loading estimates for both dissolved and solid-phase pollutant loadings.

Some field practices cannot be evaluated using the methodology presented in this section. For example, changes in the average time of planting of a crop may increase or decrease average pollutant loading; however, variations in the time of planting or harvest are not included in the methodology. In general, a **practice may be evaluated if it can be represented by changes in the input data parameters listed in Table A-9 for each pollutant.** A number of soil water and nutrient control practices are evaluated in Table A-10 for their effect on each input parameter. In each case, a (+) indicates that use of the practice will increase the level of that parameter in the predictive equations, a (-) indicates a decrease in that parameter, and a blank indicates that the practice will not affect the level of that parameter.

TABLE A-9. INPUT DATA REQUIREMENTS, COMPUTATIONAL PROCEDURE, AND RESULTING LOADING ESTIMATES BY USE OF THE PREDICTIVE EQUATIONS

POLLUTANT:	SOLID-PHASE N	SOLID-PHASE P
INPUT DATA PARAMETERS:	Total soil N concentration S_{SN} (mg/kg)	Total soil P concentration S_{SP} (mg/kg)
	USLE factors: K Slope (%) Slope length (m) C P	USLE factors: K Slope (%) Slope length (m) C P
	Enrichment ratio for soil N in eroded soil	Enrichment ratio for soil P in eroded soil
COMPUTE EDGE-OF-FIELD LOADINGS:	1) Compute average annual soil erosion by eq. 10 (T/ha-yr)	1) Compute average annual soil erosion by eq. 10 (T/ha-yr)
	2) Compute average annual total N loss in eroded soil by eq. 11 (kg/ha-yr)	2) Compute average annual total P loss in eroded soil by eq. 12 (kg/ha-yr)
ESTIMATE NUTRIENT DELIVERY:	Compute sediment delivery by eq. 16 or 18	Compute sediment delivery by eq. 16 or 18
POLLUTANT:	**DISSOLVED N**	**DISSOLVED P**
INPUT DATA PARAMETERS:	Inorganic N in fertilizer F_N (10^2 kg/ha-yr)	Available P in fertilizer F_P (kg/ha-yr)
	Soil organic N S_N (10^3 kg/ha-10 cm)	Soil available P S_P (kg/ha-10 cm)
	Curve number CN_{II}	Curve number CN_{II}
	Soil available water capacity AW (cm/cm)	Soil available water capacity AW (cm/cm)
	Soil hydrologic group	Soil hydrologic group
	Average annual precipitation $\overline{Pr}$ (cm)	Average annual precipitation $\overline{Pr}$ (cm)
		Soil bulk density ρ (g/cm^3)
		Soil pH
		Soil clay content %C (%)

(cont.)

TABLE A-9. (Continued)

COMPUTE EDGE-OF-FIELD LOADINGS:	1) Compute annual runoff by eq. 1 & 3 (cm/yr)	1) Compute annual runoff by eq. 1 and 3 (cm/yr)
	2) Compute annual percolation by eq. 2 & 4 (cm/yr)	2) Compute β from pH and %C by eq. 8 (1/kg)
	3) Compute average dissolved N concentration in percolation by eq. 6 (mg/l)	3) Compute γ_p from β and ρ by eq. 9 (dmless)
	4) Compute average dissolved N concentration in percolation by eq. 6 (mg/l)	4) Compute average dissolved P concentration in runoff by eq. 7 (mg/l)
	5) Compute average annual dissolved N loadings in runoff and percolation by eq. 13 & 14 (kg/ha-yr)	5) Compute average annual available P loading in runoff by eq. 15 (kg/ha-yr)
ESTIMATE NUTRIENT DELIVERY:	Average annual stream dissolved N loading $\cong$ runoff N plus percolation N	Average annual stream dissolved P loading $\leq$ runoff P

TABLE A-10. EFFECTS OF CHANGES IN MANAGEMENT PRACTICES ON INPUT PARAMETERS TO NUTRIENT LOSS PREDICTIVE EQUATIONS[1]

PRACTICE	PARAMETER[2]						
	F_N	F_P	S_N	S_P	CN	C	P
Contouring					-		-
Terracing					-		-
Reduced tillage					-	-	
Reduced fertilizer applications	-	-					
Incorporation of crop residues			+	+	-	-	
Substitution of manure for chemical fertilizers	-	-	+	+			
Winter cover crops			+	+	-	-	
Sod-based rotations	-	-			-	-	

1. + indicates an increase in the parameter with the practice, a - indicates a decrease, and a blank indicates no effect on the parameter. All practices are as compared to a straight-row tilled, chemically fertilized crop with no winter cover

2. All other parameters in the predictive equations are unaffected by these crop management practices

TABLE A-11. GENERALIZED AVERAGE ANNUAL C FACTOR FACTORS[a/]

Region	Corn or Soybeans				
	No-Till	Fall Plow, Residues Left	Fall Plow, Residues Removed	Spring Plow, Residues Left	Spring Plow, Residues Removed
1	.02 - .22	.35 - .44	.45 - .53	.23 - .37	.32 - .55
2	.02 - .22	.35 - .44	.45 - .53	.23 - .37	.32 - .55
3	.02 - .20	.30 - .39	.38 - .48	.20 - .33	.27 - .51
4	.02 - .21	.32 - .40	.41 - .50	.21 - .34	.29 - .52
5	.02 - .21	.31 - .41	.41 - .50	.20 - .34	.29 - .53
6	.02 - .20	.29 - .37	.37 - .46	.19 - .32	.25 - .50
7	.02 - .21	.31 - .40	.40 - .49	.20 - .33	.28 - .52
8	.02 - .22	.29 - .38	.38 - .48	.18 - .32	.27 - .51
9	.02 - .20	.25 - .33	.31 - .42	.16 - .29	.22 - .48
10	.02 - .22	.27 - .36	.35 - .45	.17 - .31	.25 - .50
11	.02 - .24	.31 - .42	.43 - .52	.19 - .34	.31 - .54
12	.02 - .25	.34 - .45	.47 - .55	.21 - .37	.34 - .58
13	.02 - .27	.34 - .47	.50 - .58	.20 - .37	.36 - .59
14	.02 - .26	.34 - .47	.50 - .58	.24 - .39	.42 - .56
15	.02 - .26	.34 - .47	.50 - .58	.21 - .37	.37 - .59
16	.02 - .22	.32 - .41	.42 - .51	.21 - .34	.30 - .54
17	.02 - .23	.33 - .43	.45 - .53	.21 - .36	.32 - .55
18	.02 - .27	.37 - .51	.55 - .62	.23 - .40	.41 - .62
19	.02 - .26	.32 - .45	.47 - .56	.19 - .35	.34 - .57
20	.02 - .25	.32 - .43	.45 - .54	.19 - .34	.32 - .55
21	.02 - .25	.32 - .43	.46 - .54	.18 - .34	.32 - .56
22	.02 - .23	.31 - .41	.42 - .51	.20 - .34	.29 - .53
23	.02 - .24	.33 - .44	.46 - .54	.21 - .36	.33 - .56
24	.02 - .24	.33 - .44	.45 - .54	.20 - .36	.33 - .56
25	.02 - .23	.31 - .41	.43 - .51	.19 - .34	.30 - .54
26	.02 - .22	.28 - .38	.38 - .48	.17 - .31	.26 - .51
27[b/]					

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a/ Ranges represent low and high productivity or low and high levels of spring crop residues.
b/ Distribution of rainfall data unavailable for region 27.

TABLE A-11. (cont.)

	Corn with Winter Cover		Continuous Hay
No tillage	0.07 - 0.15	Grass and legume mix	0.004 - .010
Strip-till, straight row	0.12 - 0.21	Clover	0.015
Strip-till on contour	0.11 - 0.18	Alfalfa	0.020
Turn-plow	0.28 - 0.43		

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[1] Ranges represent low and high productivity or low and high levels of spring crop residues

PREDICTION OF SOLID-PHASE EDGE-OF-FIELD NUTRIENT LOADINGS

Solid-phase nitrogen and phosphorus losses in runoff are dependent on the detachment and transport of soil particles from the field. The primary mechanism for soil detachment on the field is rainfall impact, although small amounts of erosion may result from snowmelt movement.

Gully and channel erosion may also contribute to stream sediment loading; however, these are off-field effects, and form part of the sediment delivery process. The present discussion concerns only rainfall erosion.

Average annual soil erosion to edge-of-field under a specific practice is predicted through application of the USLE (Wischmeier and Smith, 1978):

$$A = 2.24\ R\ K\ LS\ C\ P \tag{10}$$

where A = average annual soil erosion (T/ha-yr)
R = rainfall-runoff factor
K = soil erodability factor
LS = slope-length factor
C = crop cover and management factor
P = support practice factor

Methods for obtaining field-specific values of R, K, LS, C, and P are given in Wischmeier and Smith (1978). The crop cover factor C may also be obtained from the generalized values in Table A-11. These factors were determined by estimating an average time period for each crop stage (fallow, seedbed, crop establishment, crop development, maturing, and post-harvest) for each crop and region, based on the average dates of plant and harvest (U.S. Department of Agriculture, 1972) and the crop development rates given in Table A-5. For each crop stage, a C factor was picked for both low and high productivity (or low and high levels of crop cover). These C factors were multiplied by the average fraction of yearly erosion which occurs in each crop stage, and the products were summed over all crop stages to obtain an average annual C factor which is reflective of both crop management and the distribution of erosive rainfall during the year.

In addition to soil erosion estimates, prediction of solid-phase nutrient loss requires an estimate of the nitrogen and phosphorus concentrations in the eroded soil. The level of these nutrients will depend on the parent material, additions to fertility through manure applications or plowing under crop residues, or other factors. It is therefore impossible to estimate these nutrient levels for specific field without some form of sampling, either directly in the field, or by monitoring nutrient concentrations in sediment carried in runoff water. If soil sampling is used, the soil nutrient concentrations should be multiplied by an appropriate enrichment ratio because eroded soil particles are commonly lighter and higher in organic matter and clay than the remaining surface soil, and will therefore contain higher concentrations of both solid-phase N and P. Suggested ranges of the enrichment ratio are 2.0 and 4.3 for soil N and 1.5 to 3.4 for soil P (McElroy et al., 1976). Specific values of 2.5 for soil N and 2.0 for soil P are used in the examples in Section 4.

Edge-of-field loadings of N and P in eroded soil are computed by combining the USLE with soil nutrient concentrations and enrichment ratios for N and P:

$$SN = 0.001\ ER_N\ A\ S_{SN} \qquad (11)$$

$$SP = 9.001\ ER_p\ A\ S_{SP} \qquad (12)$$

where SN = average annual solid-phase N loss in eroded soil (kg/ha-yr)
SP = average annual solid-phase P loss in eroded soil (kg/ha-yr)
ER_N, ER_P = enrichment ratio for soil N and P (dmless)
A = average annual soil erosion (T/ha-yr)
S_{SN} = concentration of organic N in surface soil (mg/kg)
S_{SP} = concentration of solid-phase P in surface soil (mg/kg)

PREDICTION OF DISSOLVED EDGE-OF-FIELD NUTRIENT LOADINGS

Through repeated application of the CNS model (see Section 2), the following predictive equations for dissolved nutrient losses in runoff and percolation were derived for the crops and practices listed in Table A-8:

Runoff and Percolation Volume

$$\%R = a\ CN + b \qquad (1)$$

$$\%P = a\ \ CN + b \qquad (2)$$

where %R = average percent of annual precipitation appearing as direct runoff
%P = average percent of annual precipitation which percolates below 30 cm.
$CN = \frac{100}{100 - CN_{II}}$ where CN_{II} = crop curve number for average soil moisture (antecedent moisture condition II)
a, b, a , b = constants for each crop, soil, and cropping practice

and,

$$R = \frac{(\%R)\ (\overline{Pr})}{100} \qquad (3)$$

$$P = \frac{(\%P)\ (\overline{Pr})}{100} \qquad (4)$$

where R = average annual direct runoff (cm)
P = average annual percolation (cm)
Pr = average annual Precipitation (cm)

Dissolved Nutrient Concentrations in Runoff and Percolation

$$K_{RN} = a_0 + a_1\hat{CN} + a_2F_N + a_3S_N + a_4F_N\hat{CN} + a_5S_N\hat{CN} \qquad (5)$$

$$K_{PN} = b_0 + b_1\hat{CN} + b_2F_N + b_3S_N + b_4F_N\hat{CN} + b_5S_N\hat{CN} \qquad (6)$$

$$K_{RP} = \gamma_P\ (C_0 + c_1\hat{CN} + c_2F_P + c_3S_P + c_4F_P\hat{CN} + c_5S_P\hat{CN}) \qquad (7)$$

where K_{RN} = average concentration of dissolved N in runoff (mg/ℓ)
K_{PN} = average concentration of dissolved N in percolation (mg/ℓ)
K_{RP} = average concentration of dissolved P in runoff (μg/ℓ)
F_N = annual fertilizer and manure inorganic N input (10^2 kg/ha-yr)
S_N = soil organic N in the surface 10 cm (10^3 kg/ha)
γ_P = adjustment factor for soil P adsorption capacity (dmless)
F_P = annual fertilizer and manure available P input (kg/ha-yr)
S_P = soil available P in the surface 10 cm (kg/ha)
a_i, b_i, c_i = constants for each crop, soil, and cropping practice

$$\gamma_P = \frac{84.5}{\rho\ \beta} \qquad (9)$$

where ρ = soil bulk density in the surface 10 cm (g/cm^3)
β = soil available P adsorption coefficient $\left(\frac{mg/kg}{mg/\ell}\right)$

and $$\beta = 5.1 + 2.2\ (\%C) + 26.4\ (pH - 6.0)^2 \qquad (8)$$

where %C = percent clay content (soil particles < 0.002 mm in diameter) in the surface 10 cm
pH = average pH of surface 10 cm

Dissolved Nutrient Loading in Runoff and Percolation

Average dissolved nutrient loading to edge-of-field is found by combining the runoff, percolation, and nutrient concentration estimates:

$$DNR = 0.1\ (R)\ (K_{RN}) \qquad (13)$$

$$DNP = 0.1\ (P)\ (K_{PN}) \qquad (14)$$

$$DPR = 0.0001\ (R)\ (K_{RP}) \qquad (15)$$

where DNR = average annual dissolved N loading in runoff (kg/ha-yr)
DNP = average annual dissolved N loading in percolation (kg/ha-yr)
DPR = average annual dissolved P loading in runoff (kg/ha-yr)

IMPLEMENTATION OF THE NUTRIENT LOADING PREDICTIVE EQUATIONS

The procedure to be followed to implement the predictive equations may be broken down into four steps for dissolved nutrient loadings and three steps for solid-phase nutrient loadings.

Dissolved Nutrient Loadings

1) Obtain values for input parameters (CN, $\overline{Pr}$, F_N, F_P, S_N, S_P, AW, ρ, %C, pH)
   a) Curve number factor CN is equal to $100/(100-CN_{II})$, where CN_{II} is the SCS curve number for the crop for average moisture conditions (AMC II). Curve number is obtainable from Volume II of Stewart *et al.*, (1976), or Ogrosky and Mockus (1964).
   b) Fertilizer application levels F_N and F_P include all inorganic N and crop available P applied per year. If manure is applied, the amount of inorganic N in the manure that is volatilized before incorporation in the soil must be subtracted from F_N. Average fertilization levels, which may be used in the absence of specific field data, are given in Table A-12 (Beaton and Tisdale, 1969).
   c) Soil organic N and available P levels must be determined by soil sampling in the field under study.
   d) All other input parameters (Pr, AW, ρ, %C, and pH) are constants for the particular field under study. Values of ρ, %C, and pH are needed only if an estimate of average dissolved P loading in runoff is desired. Soil bulk density, soil available water capacity, and clay content are usually available from soil surveys, whereas soil pH should be determined by sampling in the field.

2) Compute average annual runoff and percolation

Given field-specific values for CN and $\overline{Pr}$, equation 1 through 4 may be used to estimate average annual runoff and percolation given the appropriate values for a, b, a , and b from Appendix III. The coefficients in Appendix C are chosen by crop, time of plowing, soil hydrologic group, geographic region, and soil available water capacity (AW, as a percent of soil volume). The appropriate table may be most easily located by reference to the list of tables at the beginning of Appendix III. Average runoff and percolation estimates for available water capacities intermediate to those listed in Appendix III should be determined by interpolation.

3) Compute average dissolved N concentrations in runoff and percolation and dissolved P concentrations in runoff

Nutrient concentrations are determined in a manner similar to that for runoff and percolation volume. Given values for CN, F_N, and S_N, dissolved

TABLE A-12. AVE. ANNUAL NITROGEN & PHOSPHORUS APPLICATIONS IN FERTILIZER (KG/HA-YR) FOR MAJOR CROPS IN EACH STUDY REGION (Beaton and Tisdale, 1969)

REGION	CROP									
	Corn Grain		Corn Silage		Hay		Soybeans		Corn with Winter Wheat	
	N	P	N	P	N	P	N	P	N	P
1	65	15	80	15	35	20	10	15	100	25
2	65	15	80	15	35	20	10	15	100	25
3	95	20	105	25	40	25	10	15	-	-
4	85	20	80	20	40	20	5	10	-	-
5	105	25	130	30	45	30	10	20	-	-
6	100	15	100	15	10	20	5	10	130	25
7	100	15	100	15	10	20	5	10	130	25
8	140	25	140	25	30	25	10	30	200	50
9	90	20	110	25	-	-	10	20	155	40
10	90	20	110	25	-	-	10	20	155	40
11	105	25	120	25	-	-	15	20	165	40
12	100	20	110	25	50	25	15	25	170	40
13	100	20	120	25	-	-	15	25	170	40
14	140	25	140	25	-	-	15	25	-	-
15	110	20	140	25	-	-	10	25	-	-
16	120	25	175	45	40	30	10	20	175	60
17	140	25	155	35	50	30	5	20	195	55
18	130	30	150	35	30	45	0	35	180	65
19	120	30	130	35	30	30	10	15	175	50
20	140	30	180	35	-	-	10	20	235	55
21	110	20	140	25	-	-	0	20	-	-
22	130	30	130	30	25	25	-	-	190	55
23	165	60	165	20	65	20	-	-	-	-
24	90	20	120	50	50	40	-	-	-	-
25	120	20	150	25	30	25	10	30	280	50
26	140	30	175	25	-	40	10	30	280	50
27	175	40	200	50	-	-	0	30	-	-

N concentrations in runoff and percolation may be computed from equations 5 and 6 given the appropriate values of a_i and b_i from Appendix III. Dissolved P concentrations in runoff may be computed from CN, F_P, S_P, ρ, %C, and pH using equations 7, 8, and 9 and the appropriate values for c_i from Appendix III. The coefficients in Appendix III are selected by crop, time of plowing, time of fertilization, soil hydrologic group, geographical region, and soil available water capacity (AW).

4) Compute average annual dissolved N and P loadings

Average annual dissolved N loadings in runoff and percolation and dissolved P loadings in runoff are found by combining average annual runoff and percolation estimates from step 2 with the average nutrient concentrations from step 3, according to equations 13, 14, and 15.

Solid-phase Nutrient Loading in Runoff

1) Obtain values for input parameters (S_{SN}, S_{SP}, R, K, LS, C, P, ER_N, ER_P)

Soil concentrations of solid-phase N and P (S_{SN}, S_{SP}) should be obtained by soil sampling in the field or by analysis of eroded soil. Factors for the USLE (equation 10) may be taken from Wischmeier and Smith (1978), or generalized C factors may be taken from Table 11. Enrichment ratios for soil N and P are variable, but may be chosen as $ER_N = 2.5$ and $ER_P = 2.0$.

2) Compute average annual soil erosion

Average annual soil loss to edge-of-field is computed using the USLE and the values derived for R, K, LS, C, and P for each study field.

3) Compute average annual solid-phase nutrient loss

Average annual solid-phase N and P loss to edge-of-field is found by substituting the computed value for average annual soil erosion A from step 2 and the soil nutrient concentrations and enrichment ratios from step 1 into equations 11 and 12.

Examples of each of these procedures are given in Section 4 of this report.

DELIVERY OF CROP NUTRIENTS FROM EDGE-OF-FIELD TO SURFACE WATERS

Once estimates of edge-of-field nutrient losses have been obtained, it may be necessary to determine the nutrient fraction which will reach surface waters through direct runoff or baseflow. The various pollutant transport mechanisms may be separated into 1) dissolved pollutant transport in direct runoff; 2) sediment and solid-phase pollutant transport in direct runoff; and 3) dissolved pollutant transport in groundwater (Figure A-1). Practices designed to control pollutant transport may affect one or more of these mechanisms.

Solid-Phase Pollutant Transport in Direct Runoff

After leaving the field in surface runoff, sediment and associated pollutants may be removed from runoff by filtration and deposition. Sediment may be deposited in grassed waterways, field borders, or buffer strips, or in forest, pasture, and cropland downslope of the field. The effectiveness (percent reduction in sediment loading) of sediment control practices will depend on the specific application of that practice, and is not easily predicted from secondary information. Sediment loading reductions through the use of individual off-field practices must therefore be determined on a local level, by observing the effectiveness of each candidate practice in an existing management scheme or through monitoring of sample fields.

Sediment deposition on intervening land surfaces may be approximated by a simple distance-to-stream function if the location of the field relative to the nearest permanent water body is known, or by a watershed drainage density model in the absence of field location data. The first method requires the computation of a delivery ratio (Sd_i) for each field in a study area, and combines with the USLE to estimate the sediment contribution of each field to the receiving waters:

$$Y_i = Sd_i \, A_i \qquad (16)$$

where Y_i = in-stream sediment loading from field i (T/ha-yr)
A_i = sediment loading to edge-of-field for field i (T/ha-yr)
Sd_i = sediment delivery ratio for field i (dmless)

and

$$Sd_i = 2.5 d_i^{-0.36} \qquad (17)$$

where d_i = distance from center of field i to receiving water (m) (Smith, *et al.*, 1979). The second method computes an average watershed delivery ratio as a function of drainage density (the ratio of the sum of permanent channel lengths in the watershed to total watershed area), and assumes a relatively homogenous soil texture in the watershed:

$$Y_i = \overline{Sd} \, A_i \qquad (18)$$

where $\overline{Sd}$ = average watershed sediment delivery ratio (dmless)
Average sediment delivery ratio $\overline{Sd}$ is obtainable from Figure A-7 (McElroy *et al.*, 1976), given the reciprocal of drainage density in km^2/km or mi^2/mi and the predominant soil texture in the watershed.

Dissolved Nutrient Delivery in Direct Runoff

The fraction of runoff which reaches surface waters depends primarily on the location of the field relative to the nearest conveyance channel. If the field drains directly into a stream or unimproved drainage ditch, we may assume that all runoff will enter the surface water system. If the field is separated by forest, pasture, or other cropland, some or all of the runoff

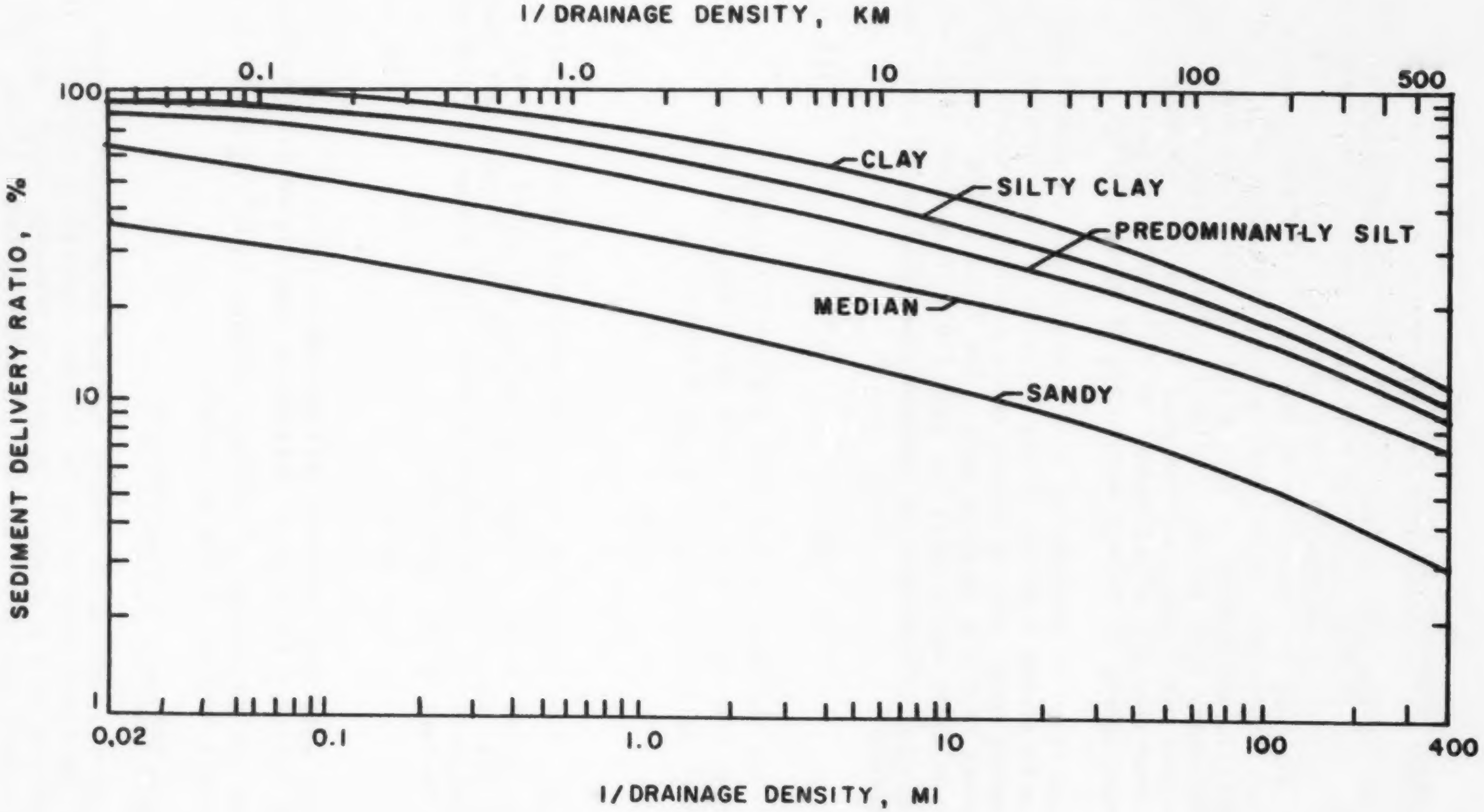

FIGURE A-7. WATERSHED SEDIMENT DELIVERY AS FUNCTION OF DRAINAGE DENSITY AND SOIL TEXTURE (McELROY ET AL., 1976) may be captured in the intervening area through ponding and subsequent infiltration. However, diffuse runoff from the field may quickly coalesce into small intermittent streams of higher velocity, which may reach a permanent channel without significant reduction in flow volume. A reasonable assumption is that 100% of direct runoff will reach a surface water body, unless diversions or detention ponds are used to redirect the flow to a place where infiltration can occur. Dissolved nitrogen is generally conserved in runoff, and hence all dissolved N lost from the field in runoff will enter the surface water systems. Dissolved phosphorus may be partially adsorbed by suspended sediment during transport or after deposition in the stream. The dissolved P trapped by sediment may reappear in the stream if the deposited or trapped sediment is detached by a later storm event. Complete delivery to the stream of dissolved P in runoff is a conservative assumption, although this is not a highly reliable estimate.

Dissolved Pollutant Transport in Groundwater

Percolation below the root zone will travel to the groundwater table, and may appear as baseflow in streams or lakes. The transport process may occur over a long period, during which time the nutrients carried in percolation may be diluted or changed in form. Dissolved P in percolation will reach equilibrium with the adsorbed phase in deep soil layers before reaching surface waters. The equilibrium concentration in groundwater reaching the stream or lake will therefore be close to background levels. Conversely, dissolved N is essentially conserved in groundwater, and field losses of dissolved N may reappear in baseflow. Although the eventual destination or timing of reappearance of percolated N from each field may not be known, the total watershed N flux reaching surface waters in baseflow should be well predicted by the sum of the individual field loadings in percolation, as determined by the predictive equations for dissolved N in percolation.

SECTION 4

DEMONSTRATION OF THE USE OF THE NUTRIENT LOADING PREDICTIVE EQUATIONS

Implementation of the nutrient loading equations is best demonstrated through examples of their use. In this section, two situations are considered: first, runoff and nutrient loading estimates are computed for a hypothetical cropping scheme in three different geographic regions; and second, the predictive equations are utilized to predict average annual nutrient loadings for the Honey Creek watershed in northern Ohio.

LOADING ESTIMATES FOR A HYPOTHETICAL CROP SITUATION

Consider a straight-row corn crop on a soil of hydrologic group C, fertilized in the spring and turn or moldboard plowed after harvest in the fall. The crop practice and soils data necessary to use the predictive equations are given in Table A-13. In order to demonstrate the variation in nutrient loading between locations, loading estimates are computed for this crop in three geographic regions: southern Minnesota (region 4), central Texas (region 10), and Pennsylvania (region 22). Within each region, two management practices, contouring and no-tillage, are analyzed for their effects on nutrient loadings as compared to base conditions.

Base Conditions (straight-row, fall-plowed, spring-fertilized)

Solid-phase Nutrient Loadings--

Solid-phase nutrient loss is predicted by combining the USLE (equation 10) with soil nutrient concentration data, according to equations 11 and 12. Rainfall-runoff factor R as obtained from Wischmeier and Smith (1978) is approximately equal to 125 for region 4, 250 for region 10, and 125 for region 22. Crop cover factors (C) for each region are obtained from Table A-11, for fall plowing with residues removed, assuming average crop cover.

Average annual soil loss is then computed as:

TABLE A-14. COMPUTATION OF AVERAGE ANNUAL SOIL LOSS UNDER BASE CONDITIONS

Region	2.24	R	K	LS	C	P	=	A
4	(2.24)	(125)	(.25)	(.354)	(.45)	(1.0)	=	11.2 T/ha-yr
10	(2.24)	(250)	(.25)	(.354)	(.40)	(1.0)	=	19.8 T/ha-yr
22	(2.24)	(125)	(.25)	(.354)	(.46)	(1.0)	=	11.4 T/ha-yr

TABLE A-13. FIELD CHARACTERISTICS FOR SAMPLE CROP

FIELD CHARACTERISTIC	VALUE	PARAMETER VALUE
Soil erosivity	0.25	K = 0.25
Slope length	61 m	
Percent slope	3%	LS = 0.354
Soil available water capacity	.15 cm/cm	AW = 15
Percent clay content	10%	%C = 10
Soil pH	6.5	pH = 6.5
Soil bulk density	1.5 g/cm^3	ρ = 1.5
		β = 33.7
		γ_P = 1.67
Soil total nitrogen content[a/]	1330 mg/kg	S_{SN} = 1330
Soil total phosphorus content[a/]	333 mg/kg	S_{SP} = 333
Soil organic N level	2000 kg/ha-10 cm	S_N = 2.0
Soil available P level	50 kg/ha-10 cm	S_P = 50
Fertilizer N application	100 kg/ha-yr	F_N = 1.0
Fertilizer P application	25 kg/ha-yr	F_N = 25

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a/ In most cases solid-phase N and P must be approximated by total soil N and P.

Average annual solid-phase N and P loadings are then computed by equations 11 and 12:

TABLE A-15 COMPUTATION OF AVERAGE SOLID-PHASE NUTRIENT LOADINGS

Region	Nitrogen:	.001	ER_N	A_b	S_{SN}	=	SN
4		(.001)	(2.5)	(11.2)	(1330)	=	37.2 kg/ha-yr
10		(.001)	(2.5)	(19.8)	(1330)	=	65.8 kg/ha-yr
22		(.001)	(2.5)	(11.4)	(1330)	=	37.9 kg/ha-yr

Region	Phosphorus:	.001	ER_P	A_b	S_{SP}	=	SP
4		(.001)	(2.0)	(11.2)	(333)	=	7.5 kg/ha-yr
10		(.001)	(2.0)	(19.8)	(333)	=	13.2 kg/ha-yr
22		(.001)	(2.0)	(11.4)	(333)	=	7.6 kg/ha-yr

Dissolved Nutrient Loadings--

From Stewart et al. (1976) crop curve number equals 88 ($\hat{CN} = 8.33$) for a straight-row crop in poor hydrologic condition (residues removed) on a C soil. Average annual precipitation for the three locations was set equal to the levels used in the CNS model simulations. Because the crop is fall plowed, Table (A)III-10 contains the appropriate values for a, b, a', and b' Nutrient coefficients are obtained from Table (A)III-11, for a fall- plowed corn crop fertilized in the spring. The following table shows the steps to be followed to compute average annual runoff and percolation from the data given and equations 1 through 4:

TABLE A-16. COMPUTATIONAL PROCEDURE FOR DIRECT RUNOFF AND PERCOLATION

			Runoff				Percolation			
region	$\overline{Pr}$ (cm/yr)	$\hat{CN}$	a	b	%R	R (cm/yr)	a'	b'	%P	P (cm/yr)
4	64.1	8.33	1.60	12.67	26.0	16.7	-1.44	30.23	18.2	11.7
10	59.2	8.33	1.33	10.63	21.7	12.8	-1.01	20.73	12.3	7.3
22	92.0	8.33	1.32	21.42	32.4	29.8	-1.32	39.79	28.8	26.5

Average annual dissolved nutrient loadings for base conditions are computed similarly, using the crop practice and soils data from Table A-12, the coefficents a_i, b_i, and c_i from Table (A)III-11, and equations 5-7 and 13-15:

TABLE A-17. COMPUTATIONAL PROCEDURE FOR DISSOLVED NUTRIENT LOADINGS

			Runoff N		Percolation N		Runoff P	
region	R (cm/yr)	P (cm/yr)	K_{RN} (mg/l)	RN (kg/ha-yr)	K_{PN} (mg/l)	PN (kg/ha-yr)	K_{RP} (µg/l)	RP (kg/ha-yr)
4	16.7	11.7	4.8	8.0	55.7	65.2	116.3	0.19
10	12.8	7.3	6.5	8.3	99.0	71.7	106.3	0.14
22	29.8	26.5	2.2	6.6	20.9	55.4	107.5	0.32

Contouring as a Management Practice

Contouring will affect both soil loss levels and dissolved nutrient losses. The only effect of contouring on soil loss is through the change in the support practice factor P, which is equal to 0.5 for contouring on a 3% slope. Soil loss and resulting solid-phase nutrient loadings are therefore cut in half for all regions:

TABLE A-18. SOIL AND SOLID-PHASE NUTRIENT LOSS WITH CONTOURING

region	Soil Loss (T/ha-yr)	Solid-phase N Loss (kg/ha-yr)	Solid-phase P Loss (kg/ha-yr)
4	5.6	18.6	3.8
10	9.9	32.9	6.6
22	5.7	19.0	3.8

The effect of contouring on dissolved nutrient loss is expressed through a change in the curve number from 88 to 84 for contouring (CN = 6.25). The same values for a, b, a', b', a_i, b_i, and c_i are used to predict runoff, percolation, and nutrient loadings:

TABLE A-19. COMPUTATION OF DISSOLVED NUTRIENT LOADINGS FOR CONTOURING

			Runoff N		Percolation N		Runoff P	
region	R (cm/yr)	P (cm/yr)	K_{RN} (mg/l)	RN (kg/ha-yr)	K_{PN} (mg/l)	PN (kg/ha-yr)	K_{RP} (µg/l)	RP (kg/ha-yr)
4	14.5	13.6	6.2	9.0	50.7	69.0	113.7	0.16
10	11.2	8.5	6.1	6.8	89.0	75.7	104.7	0.12
22	27.3	29.0	1.9	5.2	19.8	57.4	106.1	0.29

No-Tillage as a Management Practice

Tillage elimination will affect both soil loss and dissolved nutrient loadings. In this case, soil loss is decreased through a reduction in the crop C factor. Therefore, both soil and solid-phase nutrient losses will be reduced by the ratio of the no-tillage C factor to the fall plowing C factor.

TABLE A-20. SOIL AND SOLID-PHASE NUTRIENT LOSSES UNDER REDUCED TILLAGE

region	Soil loss (T/ha-yr)	Solid-phase N loss (kg/ha-yr)	Solid-phase P loss (kg/ha-yr)
4	2.7	9.1	1.8
10	5.9	19.7	4.0
22	3.0	9.9	2.0

Dissolved nutrient loss is computed using the predictive equation coefficients in Table (A)III-1 and (A)III-2 for a no-tillage corn crop fertilized in the spring. Curve number factor CN is equal to 8.33. Estimated runoff, percolation, and dissolved nutrient losses are presented below:

TABLE A-21. RUNOFF, PRECOLATION, AND DISSOLVED NUTRIENT LOADINGS FOR REDUCED TILLAGE

			Runoff N		Percolation N		Runoff P	
region	R (cm/yr)	P (cm/yr)	K_{RN} (mg/l)	RN (kg/ha-yr)	K_{PN} (mg/l)	PN (kg/ha-yr)	K_{RP} (g/l)	RP (kg/ha-yr)
4	13.1	15.2	4.4	5.8	46.8	71.1	70.6	0.09
10	10.2	9.9	5.6	5.7	82.2	81.4	63.3	0.06
22	22.3	33.9	2.0	4.5	17.7	60.0	63.7	0.14

For comparison, the nutrient loading predictions for each region under each practice are summarized in Table A-22.

NUTRIENT LOADING ESTIMATION FOR HONEY CREEK

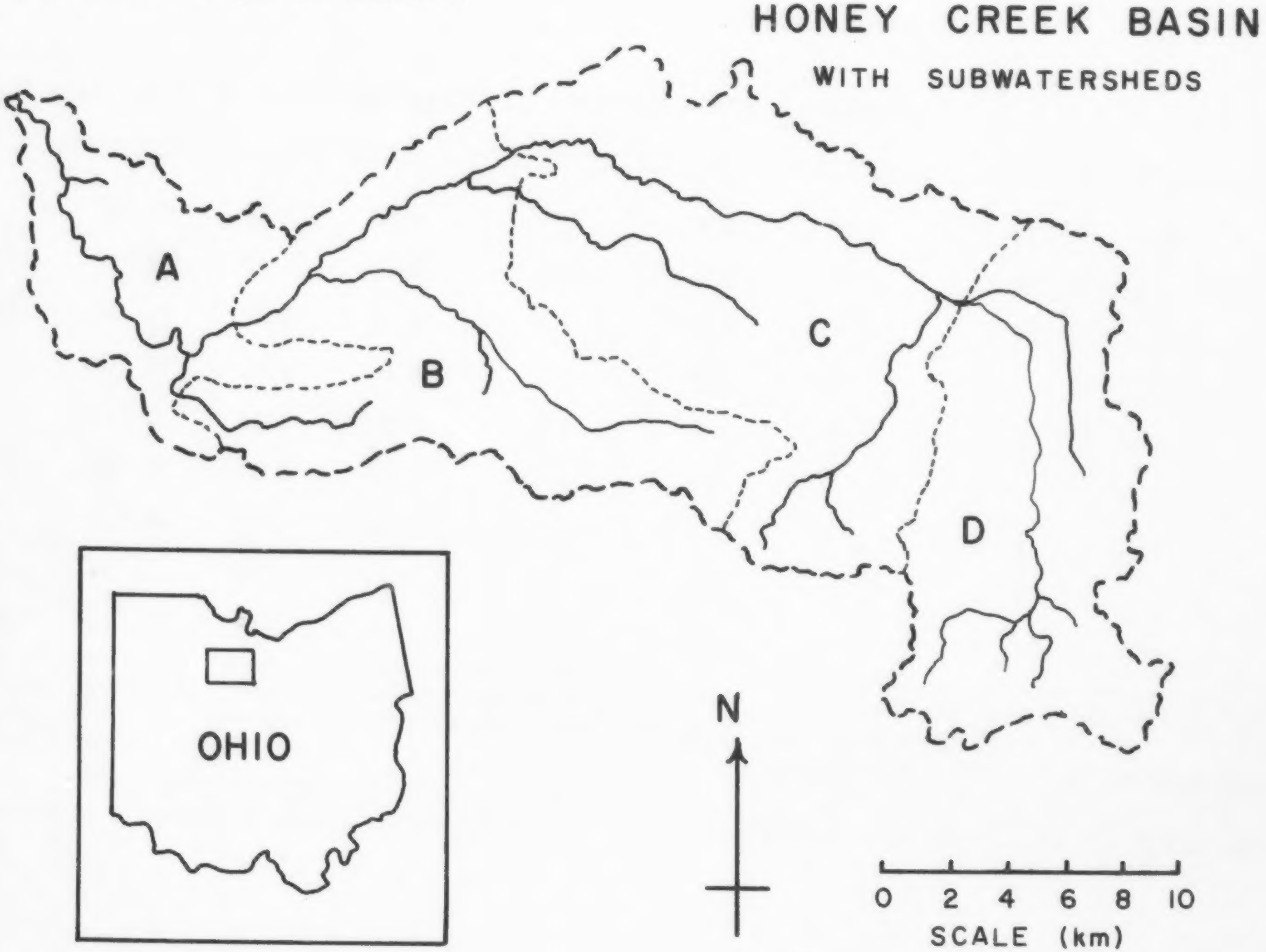
The Honey Creek watershed, situated in nothern Ohio (region 17), is a primarily agricultural watershed of approximately 45 km_2, and drains into Lake Erie through the Sandusky River (Figure A-8). The various soil types in the watershed have been combined into ten soil groups, according to similarities in texture and drainage characteristics. The characteristics of each soil group are presented in Table A-23. The values of the predictive equation parameters for each soil group based on these characteristics are also listed in Table A-23. **The watershed is separated into four subwatersheds for use in a separate economic analysis. Nutrient loadings**

TABLE A-22. SUMMARY OF RUNOFF, PERCOLATION, SOIL LOSS, AND NUTRIENT LOSS PREDICTIONS FOR SAMPLE CROP

					Dissolved Losses			Solid-phase Losses	
Region	Practice[a]	Runoff (cmyr)	Percolation (cm/yr)	Soil Loss (T/ha-yr)	Runoff N (kg/ha-yr)	Percolated N (kg/ha-yr)	Runoff P (kg/ha-yr)	N (kg/ha-yr)	P (kg/ha-yr)
4	FP, SR	16.7	11.7	11.2	8.0	65.2	0.19	37.2	7.5
	FP, C	14.5	13.6	5.6	9.0	69.0	0.16	18.6	3.8
	RT, SR	13.1	15.2	2.7	5.8	71.1	0.09	9.1	1.8
10	FP, SR	12.8	7.3	19.8	8.3	71.7	0.14	65.8	13.2
	FP, C	11.2	8.5	9.9	6.8	75.7	0.12	32.9	6.6
	RT, SR	10.2	9.9	5.9	5.7	81.4	0.06	19.7	4.0
22	FP, SR	29.8	26.5	11.4	6.6	55.4	0.32	37.9	7.6
	FP, C	27.3	29.0	5.7	5.2	57.4	0.29	19.0	3.8
	RT, SR	22.3	33.9	3.0	4.5	60.4	0.14	9.9	2.0

[a] FP = fall plow, RT = reduced tillage, SR = straight row, C = contoured

Figure A-8. Honey Creek Watershed.



are computed for each subwatershed, and are then combined to determine total watershed losses.

Soil N levels are derived from soil organic matter data obtained from local soil surveys (Soil Conservation Service, 1975), assuming a 20:1 carbon to nitrogen ratio (therefore organic matter is 5% nitrogen). Available P and solid-phase P data is averaged over all soil groups, since specific data was only available for three or four soil groups. Fertilizer N and P levels are set equal to the recommended levels for each crop in Ohio (Beaton and Tisdale, 1969), as given in Table A-12. Consequently, the nutrient loss estimates computed in this example are rough approximations, although the reduction in nutrient loading by the use of alternative practices should be well predicted.

Base conditions for the watershed are defined as fall plowing for corn and soybeans (except when grown with a winter cover crop, in which case no-tillage is assumed), and all crops planted straight-row. Hay is grown continuously without tillage. The areas of the various crops and rotations in the four subwatersheds are given in Table A-24. Nutrient loadings were estimated by applying the predictive equations to each crop in each rotation, and averaging over all crops in the rotation to obtain average annual loadings.

In addition to base conditions, three management options were analyzed for their effects on nutrient loadings to edge-of-field: 1) contouring on all crops 2) spring plowing rather than fall plowing for corn and soybeans, and 3) no-tillage rather than conventional tillage for corn and soybeans. Nutrient loadings were predicted for both spring and fall fertilization, to represent the expected range of loadings in the watershed. Contouring affects the value of CN for each crop, while variations in tillage requires a shift from one set of predictive equation coefficients to another, without any change in the input parameter values. The additional data necessary to implementing the predictive equations is as follows:

average precipitation = 95.3 cm/year
fertilizer N applications: corn = 150 kg/ha-yr (F_N = 1.5)
soybeans = 5 kg/ha-yr (F_N = 0.05)
hay = 50 kg/ha-yr (F_N = 0.5)
corn with winter cover = 200 kg/ha-yr (F_N = 2.0)
fertilizer P applications: corn = 30 kg/ha-yr (F_P = 30)
soybeans = 20 kg/ha-yr (F_P = 20)
hay = 30 kg/ha-yr (F_P = 30)
corn with winter cover = 60 kg/ha-yr (F_P = 60)

Solid-Phase Nutrient Loadings

Average annual soil loss by subwatershed and soil group as determined by the USLE is given in Table A-25. These soil loss data are combined with the soil nutrient data in Table A-23 to provide an estimate of average annual solid-phase nutrient loadings to edge-of-field in each subwatershed under base conditions. Enrichment ratios for soil nutrients were set at 2.5 for soil N and 2.0 for soil P. A similar procedure was followed for nutrient loading under each alternative management option, given the expected average annual soil loss under each practice. Table A-25 contains the estimated nutrient fluxes for each subwatershed and practice.

Dissolved Nutrient Loadings

Estimates for dissolved N and P loading for each management alternative are computed in two steps. First, average annual runoff and percolation are predicted based on crop curve numbers and soil available water capacities for each rotation and soil group. These estimates are then combined with dissolved nutrient concentrations in runoff and percolation based on soil and crop management characteristics, resulting in average annual nutrient loading estimates to edge-of-field.

Runoff and percolation estimates for base conditions in subwatershed A are contained in Table A-26. The average runoff and percolation estimates (in cm/year) for each rotation in Table A-26 are multiplied by the crop acreage data for subwatersheds B, C, and D to obtain average annual water movement for these subwatersheds, as presented in Table A-27. The effect of varying management practices on water movement in each subwatershed is estimated in Table A-28, for combinations of contouring and spring plowing or no-tillage.

Dissolved nutrient concentrations in runoff and percolation are presented for subwatershed A in Table A-29. The predictive equation coefficients listed in the appropriate table in Appendix III for each crop and practice are combined with the values of the input parameters given previously, to determine the average nutrient concentrations for each crop and rotation in Table A-29 (assuming spring fertilization for all crops). These same concentrations are combined with the predicted average annual runoff and percolation for the other subwatersheds to determine the average annual loadings in Table A-30. Predicted nutrient fluxes under various management practices are summarized in Tables A-31 and A-32. The ranges for each nutrient represent the levels of loss expected for spring fertilization vs. fall fertilization for all crops. The actual loadings should fall near to or within this range. Dissolved N loadings are usually greater for fall fertilization, as is expected. However, dissolved P loadings are higher for spring fertilization than for fall fertilization. This is due to the reinitialization of soil available P at the beginning of each model year. Because soil available P levels generally increase over the year due to fertilization, the spring applied fertilizer will have a longer period over which it may contribute to runoff losses, whereas fall applied phosphorus may only contribute for a few months before the soil P levels are reduced by reinitialization. Phosphorus loadings are rough approximations, and the decrease in P loadings due to changing the time of fertilization is not intended to be modelled by the predictive equations. Rather, the ranges in Table A-31 and A-32 for available P more closely represent the normal range to be expected for either time of fertilization.

TABLE A-23. SOIL CHARACTERISTICS IN THE HONEYCREEK WATERSHED

Soil Group	1	2	3	4	5	6	7	8	9	10
Soil classification	silty clay loam	silt loam	silty clay loam	loam	loam	loam	loam, silt loam	silt loam	silt loam	silt loam
Hydrologic group	D	C	C	B	B	C	C	D	C	C
AW(%)	20	22	20	16	16	17	16	19	19	19
Bulk density (g/cm^3)	1.53	1.56	1.53	1.67	1.67	1.72	1.45	1.59	1.72	1.72
Soil pH	6.4	6.9	6.2	6.4	6.4	6.3	6.4	5.8	6.4	6.1
Percent clay	35	15	35	20	20	20	15	15	15	15
Organic matter (%)	6.0	3.0	6.0	1.5	1.5	3.0	3.0	3.0	1.5	3.0
Available P (mg/kg)	25	25	25	25	25	25	25	25	25	25
Solid-phase P (mg/kg)	500	500	500	500	500	500	500	500	500	500
β (ℓ/kg)	86	59	83	53	53	51	42	39	42	38
γ_P	.64	.92	.67	.95	.95	.96	1.39	1.36	1.17	1.29
S_N (10^3kg/ha)	4.6	2.3	4.6	1.3	1.3	2.6	2.2	2.4	1.3	2.6
S_P (kg/ha)	38	39	38	42	42	43	36	40	43	43
S_{SN} (mg/kg)	3,000	1,500	3,000	750	750	1,500	1,500	1,500	750	1,500
S_{SP} (mg/kg)	500	500	500	500	500	500	500	500	500	500

TABLE A-24. CROP ROTATION AREAS ON HONEYCREEK BY SOIL GROUP

		Areas (ha)				
Soil	Crops in Rotation	Watershed A	Watershed B	Watershed C	Watershed D	Total for Honey Creek
1	corn soybeans	62	198	737	1451	2448
2	corn soybeans	583	383	835	33	1834
3	corn soybeans	157	60	158	868	1243
4	corn/wheat	368	13	95	-	476
5	corn soybeans	130	5	-	-	135
6	corn soybeans	485	31	415	-	931
7	corn/wheat	148	365	-	-	513
8	corn/wheat hay	368	1527	2913	830	5638
9	corn/wheat hay	676	25	518	1244	2463
	corn/wheat	-	544	-	-	544
10	corn soybeans	1645	7954	8224	1351	19174
	corn/wheat hay	1626	-	-	-	1626
	corn/wheat	-	-	4001	2040	6041
Total by sub-watershed		6248	11105	17896	7817	43066

TABLE A-25 ESTIMATED SOIL LOSS (SL), SOLID-PHASE NITROGEN LOSS (N), AND SOLID-PHASE PHOSPHORUS LOSS (P) FROM HONEY CREEK (SOIL LOSS IN 10^3 T/yr, NUTRIENT LOSS in T/yr)

Practice[a]	Subwatershed														
	A			B			C			D			Totals		
	SL	N	P	SL	N	P	SL	N	P	SL	N	P	SL	N	P
FP, SR	98	362	98	237	883	237	260	1010	260	95	456	95	692	2712	692
SP, SR	88	327	88	215	801	215	234	911	234	86	412	86	625	2452	625
RT, SR	49	180	49	106	389	106	128	497	128	47	217	47	332	1284	332
NT, SR	36	130	36	74	272	74	93	358	93	34	155	34	238	917	238
FP, C	52	193	52	128	479	128	150	585	150	52	256	52	384	1514	384
SP, C	47	174	47	116	434	116	135	529	135	47	231	47	347	1369	347
RT, C	26	96	26	57	210	57	73	283	73	26	123	26	183	713	183
NT, C	19	70	19	40	147	40	52	203	52	19	88	19	131	508	131

[a] FP = fall plow SP = spring plow RT = reduced tillage NT = no tillage
SR = straight row plowed C = contour plowed

TABLE A-26 RUNOFF AND PERCOLATION ESTIMATION FOR HONEY CREEK - SUB-WATERSHED A, BASE CONDITIONS (FALL PLOW, STRAIGHT ROW)

				Runoff				Percolation			
Soil Group	Crops in Rotation	Table	$\widehat{CN}$	%R	R (cm/yr)	R ($10^6 m^3/yr$)	Average R for Rotation ($10^6 m^3/yr$)	%P	P (cm/yr)	P ($10^6 m^3/yr$)	Average P for Rotation ($10^6 m^3/yr$)
1	Corn	C-13	11.1	39.8	38	0.2	0.2	11.8	11	0.1	0.1
	Soybeans	C-39	11.1	39.8	38	0.2		11.8	11	0.1	
2	Corn	C-10	8.3	30.5	29	1.7	1.7	19.0	18	1.1	1.1
	Soybeans	C-36	8.3	30.5	29	1.7		19.0	18	1.1	
3	Corn	C-10	8.3	30.6	29	0.5	0.5	20.6	20	0.3	0.3
	Soybeans	C-36	8.3	30.6	29	0.5		20.6	20	0.3	
4	Corn/wheat	C-24	5.3	9.8	9	0.3	0.3	38.7	37	1.4	1.4
5	Corn	C-7	5.3	17.6	17	0.2	0.2	36.8	35	0.5	0.5
	Soybeans	C-33	5.3	17.6	17	0.2		36.8	35	0.5	
6	Corn	C-10	8.3	30.8	29	1.4	1.4	23.0	22	1.1	1.1
	Soybeans	C-36	8.3	30.8	29	1.4		23.0	22	1.1	
7	Corn/wheat	C-24	8.3	19.5	19	0.3	0.3	29.7	28	0.4	0.4
8	Corn/wheat	C-24	11.1	28.4	27	1.0	1.0	20.3	19	0.7	0.7
	Hay	C-22	9.1	24.7	24	0.9		22.9	22	0.8	
9	Corn/wheat	C-24	8.3	19.6	19	1.3	1.1	28.4	27	1.8	1.8
	Hay	C-22	6.7	16.3	16	1.0		30.3	29	1.9	
	Corn/wheat	C-24	8.3	19.4	19	-	-	28.5	27	-	-
10	Corn	C-10	8.3	30.7	29	4.8	4.8	21.4	20	3.4	3.4
	Soybeans	C-36	8.3	30.7	29	4.8		21.4	20	3.4	
	Corn/wheat	C-24	8.3	19.6	19	3.1	2.8	28.4	27	4.4	4.5
	Hay	C-22	6.7	16.3	16	2.6		30.3	29	4.7	
	Corn/wheat	C-24	8.3	19.6	19	-	-	28.4	27	-	-
Totals:							14.3				15.3

TABLE A-27. RUNOFF AND PERCOLATION ESTIMATION FOR HONEYCREEK - SUB-WATERSHEDS B,C, AND D/BASE CONDITIONS

Soil Group	Crops in Rotation	Average annual runoff and percolation for rotation ($10^6 m^3/yr$)					
		Watershed B		Watershed C		Watershed D	
		runoff	percolation	runoff	percolation	runoff	percolation
1	corn soybeans	0.8	0.2	3.0	0.8	5.5	1.6
2	corn soybeans	1.2	0.7	2.4	1.5	0.0	0.0
3	corn soybeans	0.2	0.2	0.4	0.3	2.5	1.8
4	corn/wheat	0.0	0.1	0.1	0.4	-	-
5	corn soybeans	0.0	0.0	-	-	-	-
6	corn soybeans	0.0	0.0	1.2	1.0	-	-
7	corn/wheat	0.7	1.0	-	-	-	-
8	corn/wheat hay	3.9	3.2	7.3	6.0	2.1	1.7
9	corn/wheat hay	0.0	0.0	0.9	1.4	2.2	3.5
	corn/wheat	1.0	1.5	-	-	-	-
10	corn soybeans	23.2	16.2	24.0	16.8	4.0	2.8
	corn/wheat hay	-	-	-	-	-	-
	corn/wheat	-	-	7.6	10.8	3.8	5.5
Totals		31.0	23.1	46.9	39.0	20.1	16.9

TABLE A-28. AVERAGE ANNUAL RUNOFF AND PERCOLATION FOR CROP MANAGEMENT ALTERNATIVES AT HONEYCREEK($10^6 m^3/yr$)

Practice[a/]	Watershed A		Watershed B		Watershed C		Watershed D		Total for Honey Creek	
	runoff	percol.	runoff	percol.	runoff	percol.	runoff	percol.	runoff	percol.
FP, SR	14.3	15.3	31.0	23.1	46.9	39.0	20.1	16.9	112.3	94.2
SP, SR	12.4	17.2	25.6	28.5	40.4	45.5	17.8	19.1	96.2	110.3
RT, SR	12.2	17.4	24.9	29.1	39.6	46.3	17.6	19.3	94.3	112.1
FP, C	12.0	17.4	26.8	27.0	38.9	46.4	16.5	20.2	94.3	111.0
SP, C	8.9	20.5	17.8	35.9	28.0	57.3	12.5	24.2	67.2	138.0
RT, C	8.5	20.9	16.7	37.0	26.7	58.6	12.0	24.6	63.9	141.1

[a/] FP = fall plowing
SP = spring plowing
RT = reduced tillage
SR = straight-row plant
C = contour plant

TABLE A-29. NUTRIENT LOADING ESTIMATION FOR HONEYCREEK - SUB-WATERSHED A, BASE CONDITIONS (SPRING FERTILIZATION)

Soil Group	Crops in Rotation	Table	CN	K_{RN} (mg/l)	K_{PN} (mg/l)	K_{RP} (μ/l)	Runoff ($10^6 m^3/yr$)	Percol. ($10^6 m^3/yr$)	Diss. N in runoff (T/yr)	Diss. N in percol. (T/yr)	Diss. P in runoff (kg/yr)
1	Corn		11.1	9.6	104	34	0.2	0.1	1.5	6	7
	Soybeans		11.1	3.2	36	33	0.2	0.1			
2	Corn		8.3	5.5	53	48	1.7	1.1	5.6	35	82
	Soybeans		8.3	1.0	10	48	1.7	1.1			
3	Corn		8.3	7.1	73	34	0.5	0.3	2.2	15	14
	Soybeans		8.3	2.4	25	34	0.5	0.3			
4	Corn/wheat		5.3	3.0	34	66	0.3	1.4	1.0	48	22
5	Corn		5.3	2.3	27	52	0.2	0.5	0.3	7	10
	Soybeans		5.3	0.3	2	51	0.2	0.5			
6	Corn		8.3	4.7	50	55	1.4	1.1	4.1	31	77
	Soybeans		8.3	1.0	11	54	1.4	1.1			
7	Corn/wheat		8.3	4.9	48	90	0.3	0.4	1.3	20	24
8	Corn/wheat		11.1	7.2	58	97	1.0	0.7	4.3	26	85
	Hay		9.1	1.7	16	87	0.9	0.8			
9	Corn/wheat		8.3	4.9	42	85	1.3	1.8	3.5	44	93
	Hay		6.7	0.7	7	77	1.0	1.9			
	Corn/wheat		8.3	4.9	42	85	-	-	-	-	-
10	Corn		8.3	5.1	52	74	4.8	3.6	15.1	105	352
	Soybeans		8.3	1.1	11	73	4.8	3.6			
	Corn/wheat		8.3	5.8	52	94	3.1	4.4	10.6	148	256
	Hay		6.7	1.4	15	85	2.6	4.7			
	Corn/wheat		8.3	5.8	52	94	-	-	-	-	-
Totals									49.5	485	1022

TABLE A-30. NUTRIENT LOSS ESTIMATION FOR HONEYCREEK - SUB-WATERSHEDS B, C, AND D, BASE CONDITIONS[a]

		Watershed B			Watershed C			Watershed D		
Soil Group	Crops in Rotation	Runoff N (T/yr)	Percol. N (T/yr)	Runoff P (kg/yr)	Runoff N (T/yr)	Percol. N (T/yr)	Runoff P (kg/yr)	Runoff N (T/yr)	Percol. N (T/yr)	Runoff P (kg/yr)
1	Corn Soybeans	4.8	15	24	17.9	57	92	35.1	113	182
2	Corn Soybeans	3.7	21	52	8.0	46	115	0.4	1	4
3	Corn Soybeans	0.8	5	5	2.2	14	14	12.1	83	85
4	Corn/wheat	0.4	1	1	0.3	12	5	-	-	-
5	Corn Soybeans	0.0	0	0	-	-	-	-	-	-
6	Corn Soybeans	0.3	1	4	3.4	26	65	-	-	-
7	Corn/wheat	3.3	49	61	-	-	-	-	-	-
8	Corn/wheat Hay	17.6	112	355	34.1	214	678	9.7	60	192
9	Corn/wheat Hay	0.2	2	2	2.7	33	71	6.3	82	171
	Corn/wheat	5.0	63	87	-	-	-	-	-	-
10	Corn Soybeans	72.3	518	1704	75.4	531	1772	12.3	86	288
	Corn/wheat Hay	-	-	-	-	-	-	-	-	-
	Corn/wheat	-	-	-	43.4	562	701	22.1	290	365
Totals		108.4	787	2295	187.4	1495	3513	98.0	715	1287

[a] Fall plow, straight row, spring fertilization

TABLE A-31. NUTRIENT LOSS ESTIMATION FOR CROP MANAGEMENT AT HONEYCREEK - NITROGEN (T/yr)

	Watershed A		Watershed B		Watershed C		Watershed D		Totals	
Practice[a]	Runoff N	Percol. N	Runoff N	Percol. N	Runoff N	Percol. N	Runoff N	Percol. N	Runoff N	Percol. N
FP, SR	49-62	480-600	108-139	790-920	187-225	1500-1780	98-111	720-850	443-538	3490-4160
SP, SR	46-48	500-640	99-97	840-1020	173-174	1560-1910	84-88	740-900	403-408	3650-4470
RT, SR	40-48	510-640	83-97	850-1030	154-174	1580-1920	80-87	740-900	359-408	3680-4500
FP, C	34-50	510-640	78-117	840-980	126-177	1620-1930	66-85	780-930	305-430	3760-4480
SP, C	30-29	540-690	68-57	920-1130	111-102	1720-2120	53-52	830-1010	264-242	4010-4950
RT,C	22-29	550-700	44-57	940-1150	82-103	1740-2140	43-51	830-1010	192-242	4060-5000

[a] FP = fall plowing
SP = spring plowing
RT = reduced tillage
SR = straight-row plow
C = contour plow

TABLE A-32 NUTRIENT LOSS ESTIMATION FOR CROP MANAGEMENT ALTERNATIVES AT HONEY CREEK-PHOSPHORUS (kg/yr)

	------------	Watershed	------------		
Practice[a/]	A	B	C	D	Total
FP, SR	1020-790	2300-1850	3510-2690	1290-950	8120-6280
SP, SR	920-690	1980-1500	3150-2290	1190-840	7250-5330
RT, SR	890-670	1870-1450	3030-2240	1170-840	6960-5210
FP, C	830-680	1940-1630	2800-2260	990-770	6550-5340
SP, C	670-500	1410-1060	2190-1600	830-600	5090-3760
RT, C	620-480	1240-980	2000-1520	780-580	4630-3560

[a/] FP = fall plowing
SP = spring plowing
RT = reduced tillage
SR = straight-row plow
C = contour plow

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APPENDIX I

MATHEMATICAL DESCRIPTION AND VALIDATION OF THE CORNELL NUTRIENT SIMULATION MODEL

INTRODUCTION

The Cornell Nutrient Simulation (CNS) model is a mathematical model which can be used to estimate edge-of-field nutrient losses from croplands. Earlier versions of the model have been described by Tubbs and Haith (1977) and Haith (1979). The current version, as used in this study, includes several major changes from its predecessors:

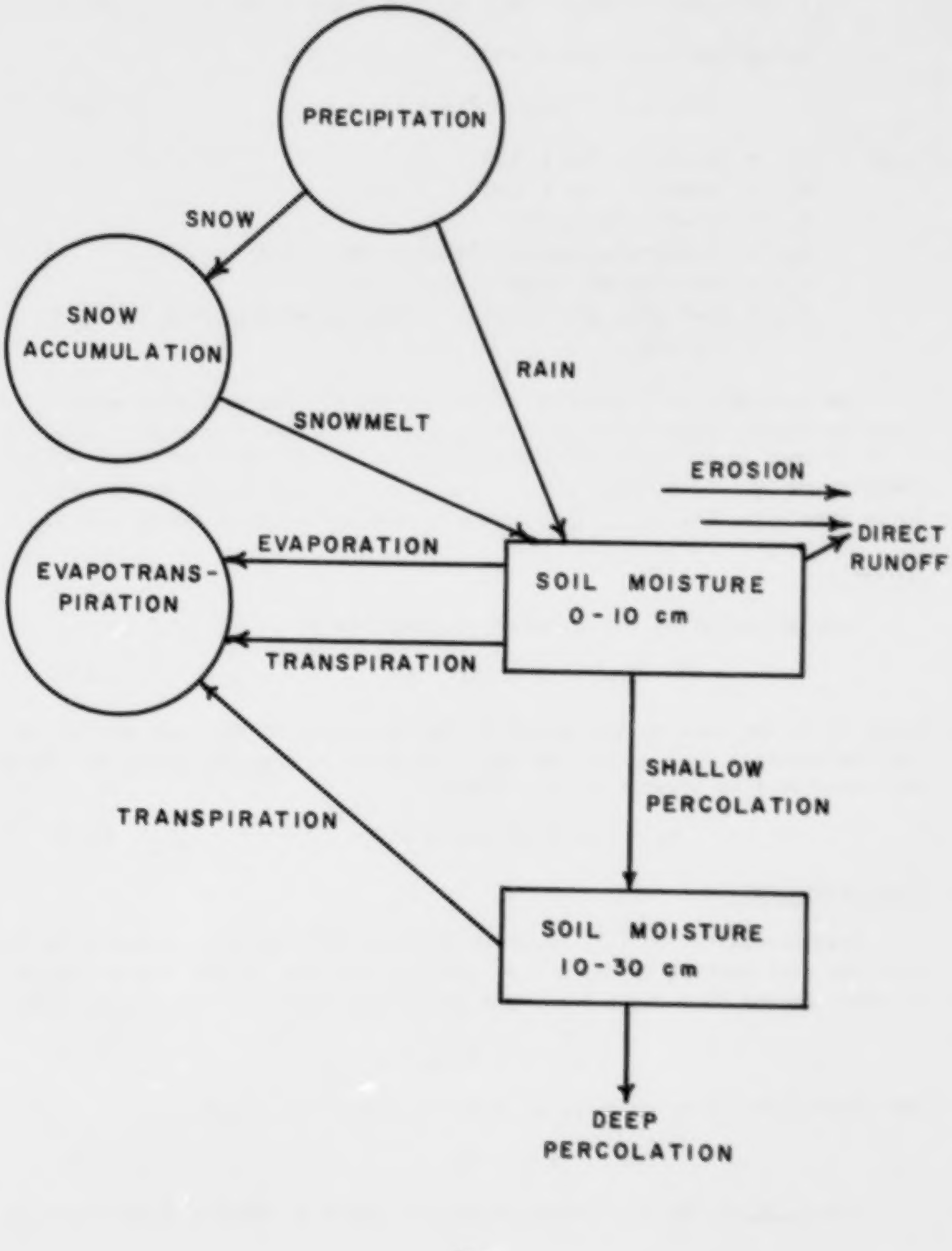
1. Water and nutrient budgets are computed for two soil layers (0-10 cm, 10-30 cm depths)
2. Snowmelt is computed by a simple degree-day method.
3. The detention parameter for the U.S. Soil Conservation Service Runoff Equation is adjusted on a continuous basis according to soil moisture.
4. Soil evaporation and plant transpiration are computed separately.
5. William's (1975) modification of the Universal Soil Loss Equation is used to compute sediment losses.
6. Concentrations of dissolved nutrients in runoff are assumed to be determined by the available nutrients in the surface cm of soil.

The overall effect of these and other minor changes have been to make the CNS model less empirical. The overall structure remains similar to earlier versions, however. **Soil moisture balances are computed with a daily time step and nutrient budgets are computed at monthly intervals. The model is deterministic; i.e., it is based on readily available soil, crop and meteorologic data and contains no calibration parameters. This appendix describes the mathematical details of the CNS model and summarizes the results of validation studies for Watkinsville, Ga. and Aurora, N.Y.**

SOIL WATER BALANCE

The soil water balance component of the CNS model provides daily estimates of direct runoff (surface and subsurface), erosion and percolation from the surface (0-10 cm) soil layer and percolation from the subsurface (10-30 cm) layer. The general structure of the mositure balance is shown in Figure (A)I-1. **The soil is assumed to drain to field capacity in one day and hence the CNS model is limited to well-drained soils without near-surface water tables or impermeable layers.** The general water mass balances are

Figure I-1. CNS soil moisture model.



Surface layer (0-10 cm):

$$d_1\theta_{1,t+1} = d_1\theta_{1t} + R_t + M_t - Q_t - E_{1t} - P_{1t} \qquad (A.1)$$

Subsurface layer (10-30 cm):

$$d_2\theta_{2,t+1} = d_2\theta_{2t} + P_{1t} - E_{2t} - P_{2t} \qquad (A.2)$$

where R_t = Rainfall, day t (cm)
M_t = Snowmelt, day t (cm)
Q_t = Runoff, day t (cm)
E_{jt} = Evapotranspiration, layer j, day t (cm)
P_{jt} = Percolation, layer j, day t (cm)
θ_{jt} = Available soil moisture, layer j, at beginning of day t (cm/cm)

The available soil mositure cannot exceed $\bar{\theta}_j$, the available water capacity (field capacity minus wilting point) of layer j (cm/cm). Rainfall R_t is assumed equal to recorded precipitation during day t provided the mean temperature T_t (°C) exceeds zero. Otherwise, the precipitation is considered to be snowfall. The soil layer depths d_j are $d_1 = 10$ cm and $d_2 = 20$ cm.

Snowmelt

Snow accumulation (cm of water) is modelled as

$$S_{t+1} = S_t + \Delta S_t - M_t \qquad (A.3)$$

where S_t is the snow on the ground at the beginning of day (cm) and ΔS_t is the new snowfall (cm) during the day. Snowmelt is computed using the degree-day equation from Stewart et al. (1976):

$$M_t = (S_t,\ 0.45T_t),\ T_t > 0 \qquad (A.4)$$

Evapotranspiration

Evapotranspiration (ET) consists of three sources, EV_t, evaporation from from the soil surface on day t (cm) and TR_{1t} and TR_{2t}, plant transpiration or water demand from the surface and subsurface layers on day t (cm). Thus

$$E_{1t} = EV_t + T_{1t} \qquad (A.5)$$

and since there is no evaporation from the subsurface layer,

$$E_{2t} = T_{2t} \qquad (A.6)$$

Both evaporation and transpiration are based on Hamon's (1961) formula for potential evapotranspiration on day t, PE_t(cm).

$$PE_t = \frac{0.021\ D_t^2}{T_t + 273}\ e_{st} \tag{A.7}$$

where D_t = daylight hours during day t
e_{st} = saturation vapor pressure, day t (mb)

Evaporation and transpiration are weighted by CP_t, the fraction of soil surface covered by crop canopy on day t. Evaporation is assumed to be a linear function of soil moisture:

$$EV_t = \text{Min}\ [(\theta_{1t}/\overline{\theta_1})\ (1-CP_t)\ PE_t;\ d_1\theta_{1t}] \tag{A.8}$$

Transpiration from the surface layer is equal to PE_t, provided sufficient soil water is present.

$$T_{1t} = \text{Min}\ (CP_t PE_t; d_1\theta_{1t} - EV_t) \tag{A.9}$$

$$T_{2t} = \text{Min}\ (CP_t\ PE_t - T_{1t}; d_2\theta_{2t}) \tag{A.10}$$

Runoff

Direct runoff is computed by the U.S. Soil Conservation Service's Curve Number Equation (Mockus, 1972; Ogrosky and Mockus, 1964):

$$Q_t = \frac{(R_t + M_t - 0.2\ W_t)^2}{R_t + 0.8\ W_t} \tag{A.11}$$

The detention parameter W_t (cm) in equation A.11 is determined from a curve number CN_t as

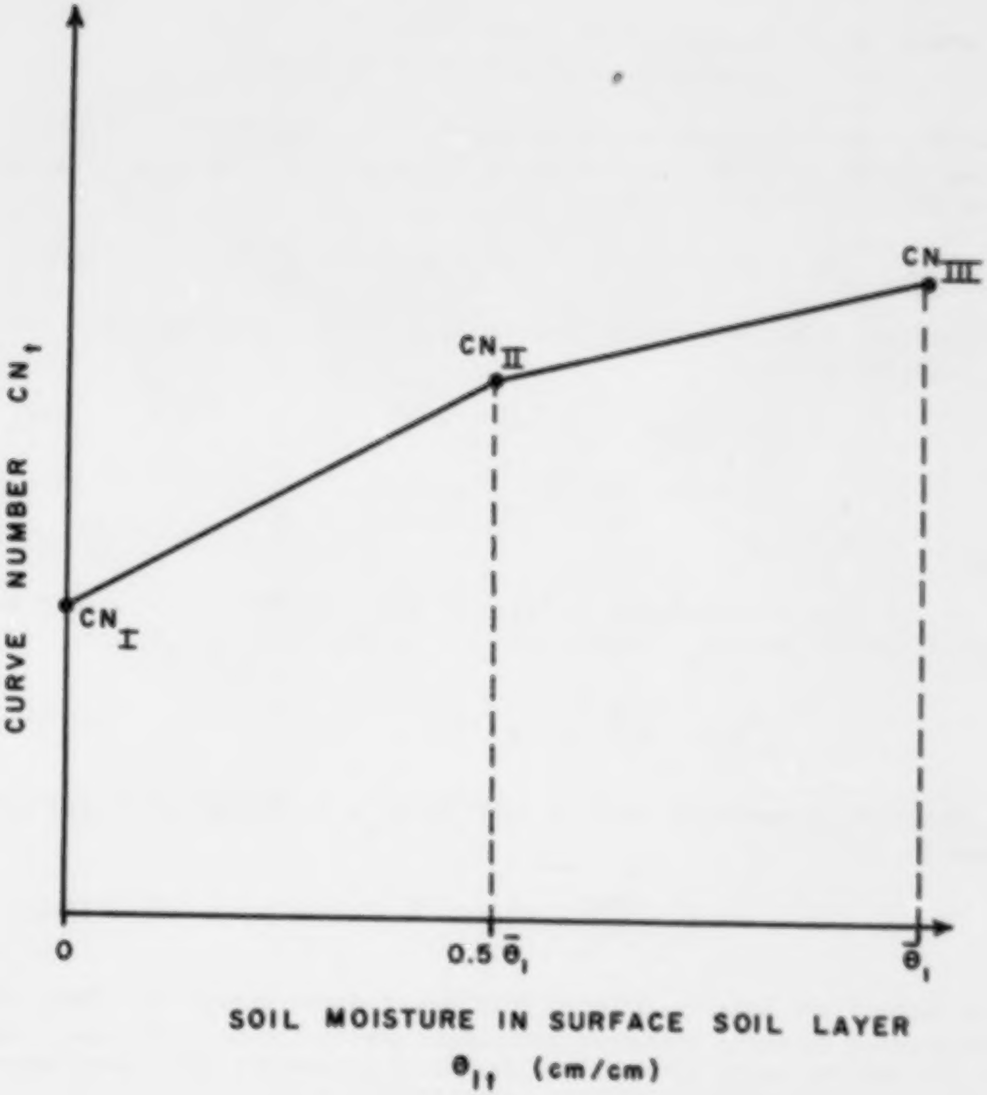
$$W_t = \frac{2540}{CN_t} - 25.4 \tag{A.12}$$

Curve numbers are usually selected from one of three values CN_I, CN_{II}, CN_{III} corresponding to three different antecedent precipitation conditions. However, in the CNS model cold-weather detention parameters are always based on the wettest antecedent moisture conditions; i.e.,

$$CN_t = CN_{III},\ \text{for } T_t < 0 \text{ or } M_t > 0 \tag{A.13}$$

During other periods, curve numbers are selected as continuous functions of soil moisture in the surface 10 cm by the method shown in Figure (A)I-2. This method is based on curves developed by the Bureau of Reclamation (1978) which assign CN_I and CN_{III} to soil moisture wilting point and field

Figure I-2. Curve number selection as a function of soil moisture.



capacity, respectively and CN_{II} to the midpoint between wilting point and field capacity. The function in Figure (A)I-2 is given by

$$CN_t = \begin{cases} CN_I + \theta_{1t}\,(CN_{II} - CN_I)/0.5\,\bar{\theta}_1 & ,\ \theta_{1t} < 0.5\,\bar{\theta}_1 \\ CN_{II} + (\theta_{1t} - 0.5\bar{\theta}_1)\,(CN_{III} - CN_{II})/0.5\theta_1, & \theta_{1t} \geq 0.5\bar{\theta}_1 \end{cases} \qquad (A.14)$$

Percolation

Percolation is computed as the excess soil water above field capacity:

$$P_{1t} = \text{Max}\,[d_1\theta_{1t} + R_t + M_t - E_{1t} - Q_t - d_1\bar{\theta}_1;\ 0] \qquad (A.15)$$

$$P_{2t} = \text{Max}\,[d_2\theta_{2t} + P_{1t} - E_{2t} - d_2\bar{\theta}_2;\ 0] \qquad (A.16)$$

Sediment Loss

The modified Universal Soil Loss Equation proposed by Williams (1975) is used to estimate edge-of-field sediment loss X_t (T/ha) due to rainfall erosion.

$$X_t = \frac{11.8}{A}\,(V_t q_t)^{0.56}\ K(LS)C_t\ P \qquad (A.17)$$

where K, (LS), C_t and P are the standard soil erodibility, topographic, cover and supporting practice factors (Wischmeier and Smith, 1978), A is the field area (ha), V_t is runoff volume (m^3) given by 100 AQ_t, and q_t is peak runoff (m^3/sec).

Peak runoff can be estimated by assuming a runoff hydrograph as shown in Figure (A)I-3. In the figure D_t is the rainstorm duration (hr), D_c is the time of concentration (hr) and D_a is the duration of initial abstraction (hr); i.e. the time from the start of rainfall until runoff begins. Since total runoff is equal to the area under the hydrograph,

$$Q_t = q_t'\,D_c + q_t'\,(D_t - D_a - D_c) = q_t'\,(D_t - D_a) \qquad (A.18)$$

where q_t is peak runoff in units of cm/hr (q_t = 0.028 q_t' A). To determine D_a, it is assumed that the duration of abstraction is proportional to the amount of abstraction ($0.2W_t$ in equation A.11). Hence $D_a/D_t = 0.2W_t/R_t$, and equation A.19 can be re-arranged to give

$$q_t = 0.028A\,\left(\frac{R_t}{D_t}\right)\left(\frac{Q_t}{R_t - 0.2W_t}\right) \qquad (A.19)$$

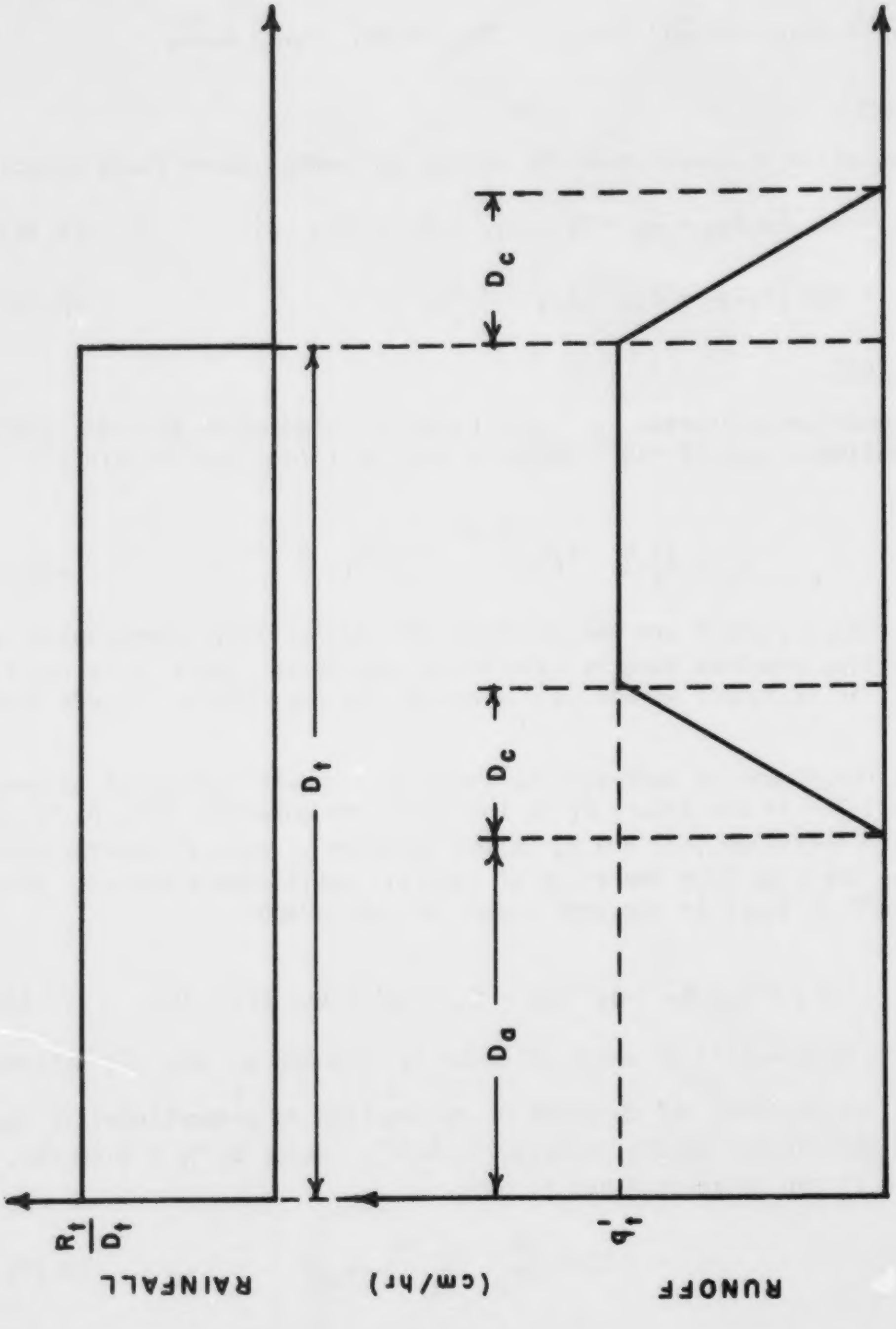


Figure I-3. Hydrograph for peak runoff estimation.

Equation A.19 weights average rainfall intensity (R_t/T_t) by the ratio of runoff to precipitation excess which is available for runoff.

Canopy Development

Evapotranspiration and sediment loss computations require estimates of CP_t, the fraction of the soil surface covered by crop canopy. In the case sediment, the cover factor C_t is a direct function of canopy (Wischmeier and Smith, 1978). If L_t is the fraction of the time period between crop emergence and full canopy which is associated with day t, the canopy factor CP_t, is estimated as

$$CP_t = \frac{1.5L_t}{0.5 + L_t} \tag{A.20}$$

This function is shown in Figure (A)I-4.

NUTRIENT MODEL

The nutrient component of the CNS model has a monthly time step. The monthly runoff, percolation and sediment loss values required for nutrient mass balances are obtained by summing the daily values predicted by the water balance component. **The nutrient balance model estimates monthly losses of dissolved and solid-phase nitrogen (N) in runoff, dissolved N in percolation, dissolved phophorus (P) in runoff and solid-phase P in runoff.** It is assumed that all dissolved nutrients are in the inorganic form and that solid-phase N is organic. Losses of solid-phase nutrients are assumed to be fixed or adsorbed to soil particles.

Nitrogen

Characteristics of the CNS model's soil N computations are shown in Figure A-5. Separate inventories of inorganic N are maintained in the top and bottom soil layers, while an organic N inventory is computed for the surface layer only. Nitrogen in either layer is assumed to be perfectly mixed. Only inorganic N in the top cm of the surface layer is considered available for runoff loss. The model neglects denitrification and other volatilization losses. Since nitrification is rapid in well-drained soils, and the model time step is large (1 mo), the nitrification step is not modelled. Nitrogen fixation is not included explicity. When legumes are modelled, it is assumed that the plants will scavenge the soil for inorganic N and fix their remaining needs. Fixed N is not considered available for loss in runoff or percolation as inorganic N.

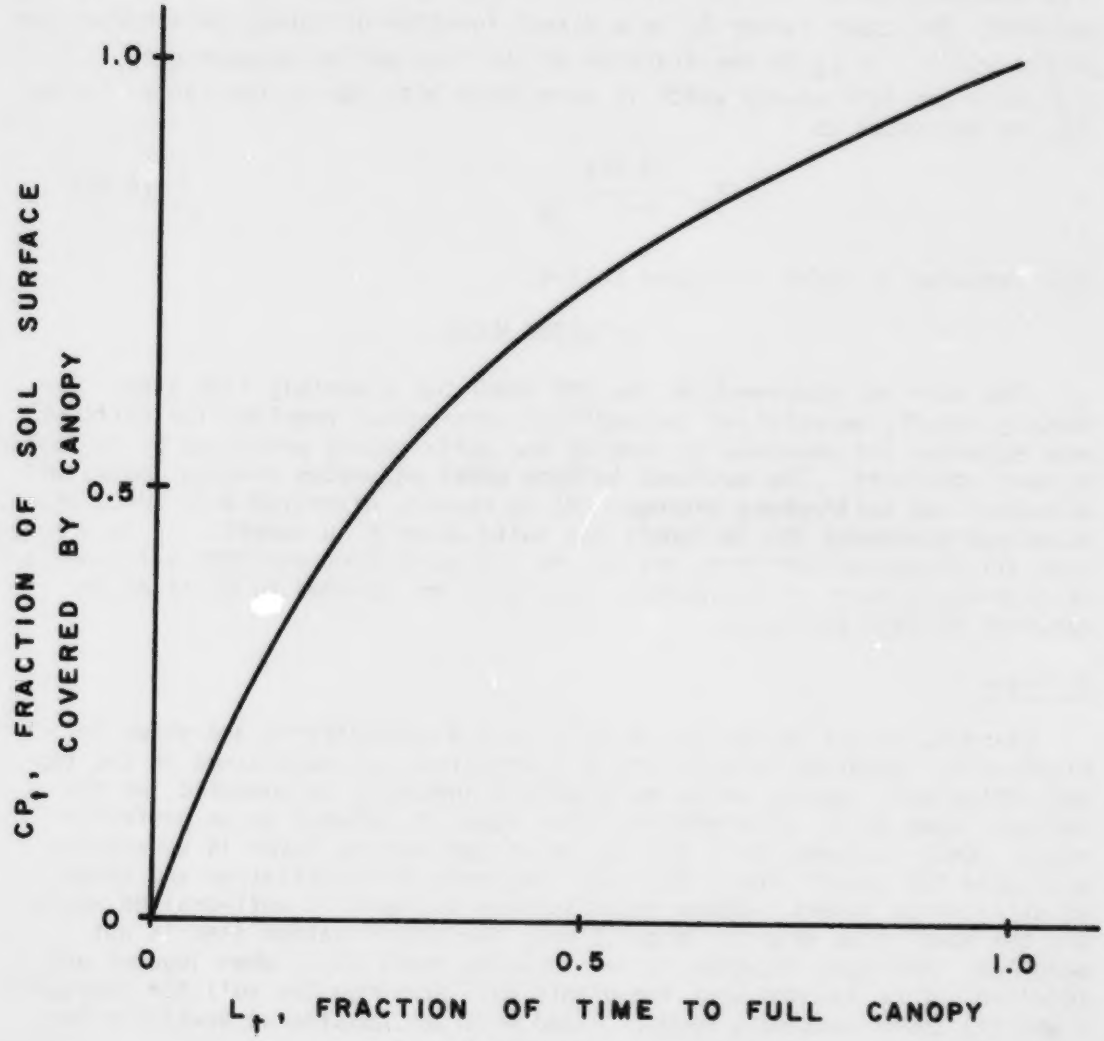
The inorganic N balances are given by

$$I_{1,n+1} = I_{1n} + FN_n + MI_n + RN_n + m_nO_n - UN_{1n} - QN_n - PN_{1n} \tag{A.21}$$

and

$$I_{2,n+1} = I_{2n} + PN_{1n} - UN_{2n} - PN_{2n} \tag{A.22}$$

Figure I-4. Canopy growth function.



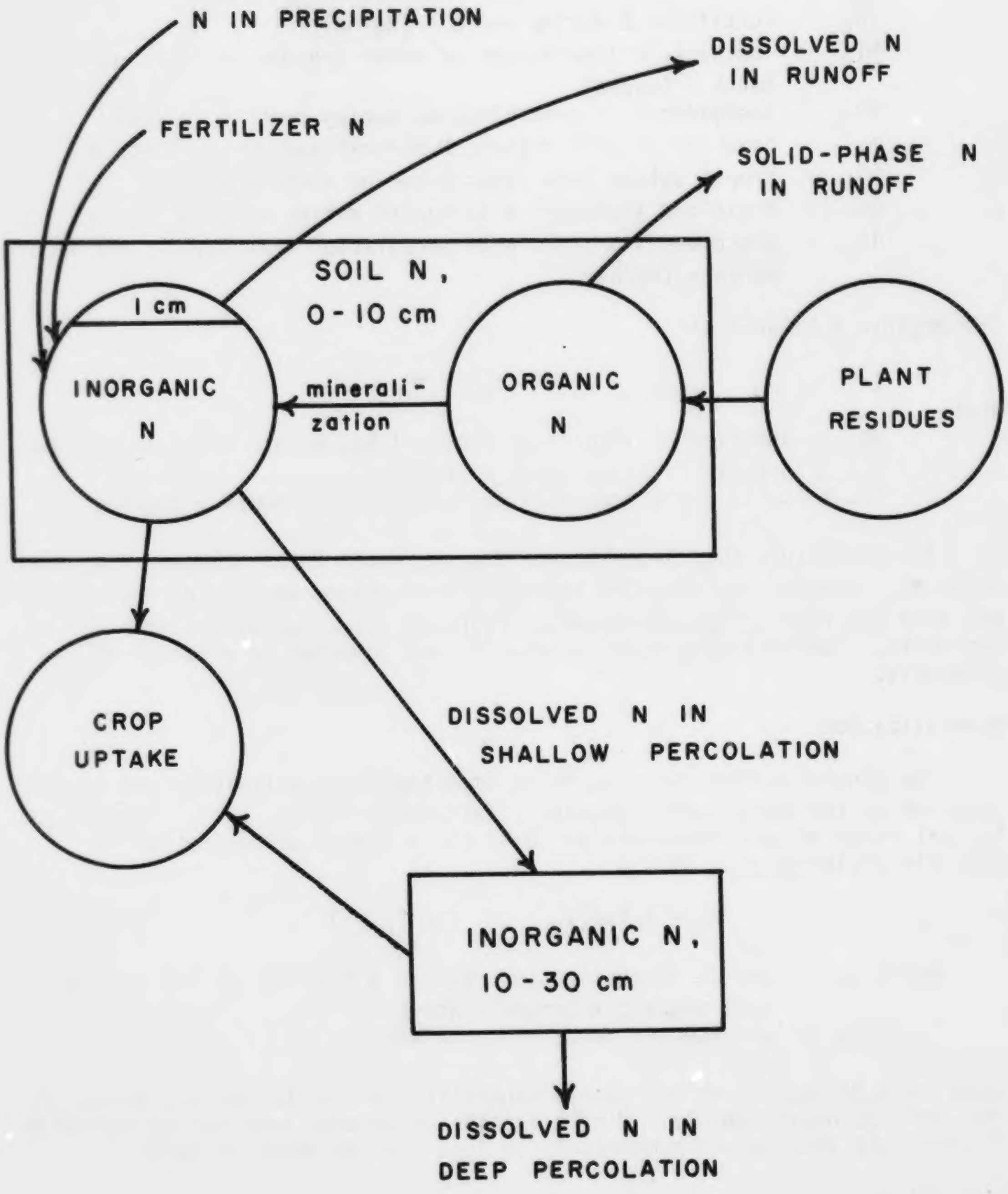


Figure I-5. CNS nitrogen model.

In these equations,

I_{jn} = soil inorganic N in layer j at beginning of month n (kg/ha)
O_n = soil organic N in layer 1 at beginning of month n (kg/ha)
FN_n = fertilizer N during month n (kg/ha)
MI_n = inorganic N from manure or other organic residues during month n (kg/ha)
RN_n = inorganic N in precipitation during month n (kg/ha)
m_n = fraction of soil organic N mineralized during month n
UN_{jn} = crop N uptake from layer j during month n (kg/ha)
QN_n = dissolved inorganic N in runoff during month n (kg/ha)
PN_{jn} = dissolved inorganic N in percolation from layer j during month n (kg/ha)

The organic N balance is

$$O_{n+1} = O_n(1 - m_n) + MO_n - XO_n \tag{A.23}$$

Where

MO_n = addition of stabilized (humus-like) manure or plant residue organic N during month n (kg/ha)
XO_n = solid-phase organic N in runoff during month n (kg/ha)

The parameters FN_n, MI_n, RN_n and MO_n are model input values. The parameter MI_n includes not only the inorganic N in manure applied during month n but also the readily degraded manure organic N which has mineralized during the month. The remaining model parameters are computed by a series of submodels.

Mineralization

The mineralization rate, m_n is assumed temperature-limited, and can be modelled by the Van't Hoff-Arrhenius relationship (Haith, 1973). Within the typical range of soil temperatures (0-20°C), a linear approximation is possible (Haith et al., 1977):

$$m_n = m_o T_n / \sum T_n \qquad \text{for } T_n \geq 0 \tag{A.24}$$

where m_o = yearly mineralization rate as a fraction of the average soil organic nitrogen content
T_n = average air temperature in month n (°C)

Equation A.24 apportions the yearly mineralization to the various months on the basis of degree-months. Mineralization is assumed zero during any month in which the average air temperature is less than or equal to zero.

Crop Uptake

Total uptake of N in month n, UN_n (kg/ha) is approximated by the sigmoid function shown in Figure (A)I-6. If sufficient inorganic N is present in the top layer, all crop N uptake is assigned to the layer; i.e. $UN_{1n} = UN_n$. Otherwise, the remaining N requirement, $UN_n - UN_{1n}$, is taken from the second layer. If UN_n exceeds total inorganic N in the two layers it is assumed that plant needs will be satisfied from N below the 30 cm depth in the soil profile. The relevant equations are

$$UN_{1n} = \mathrm{Min}[UN_n;\ I_{1n} + FN_n + MI_n + RN_n + m_nO_n] \qquad (A.25)$$

$$UN_{2n} = \mathrm{Min}[UN_n - UN_{1n};\ I_{2n} + PN_{1n}] \qquad (A.26)$$

Runoff Losses

Both runoff and percolation losses of inorganic N are based on $\overline{I}_{jn}$, the average inorganic N in layer j during month n (kg/ha):

$$\overline{I}_{jn} = \frac{I_{jn} + I_{j,n+1}}{2} \qquad (A.27)$$

Since only the N in the top cm of the surface 10 cm layer is considered available for runoff loss, the "runoff available" inorganic N is $0.1\overline{I}_{1n}$.

The portion which is actually lost is determined by the fraction of available water $R_n + M_n$ which runs off (Q_n), and hence

$$QN_n = \frac{0.1\ Q_n\ \overline{I}_{1n}}{R_n + M_n} \qquad (A.28)$$

Runoff losses of solid-phase (organic) N are a function of sediment loss and are given by

$$XO_n = \frac{ER_N X_n \overline{O}_n}{1000\rho} \qquad (A.29)$$

where

ρ = bulk density surface (10 cm) soil layer (g/cm^3)
ER_N = N enrichment ratio

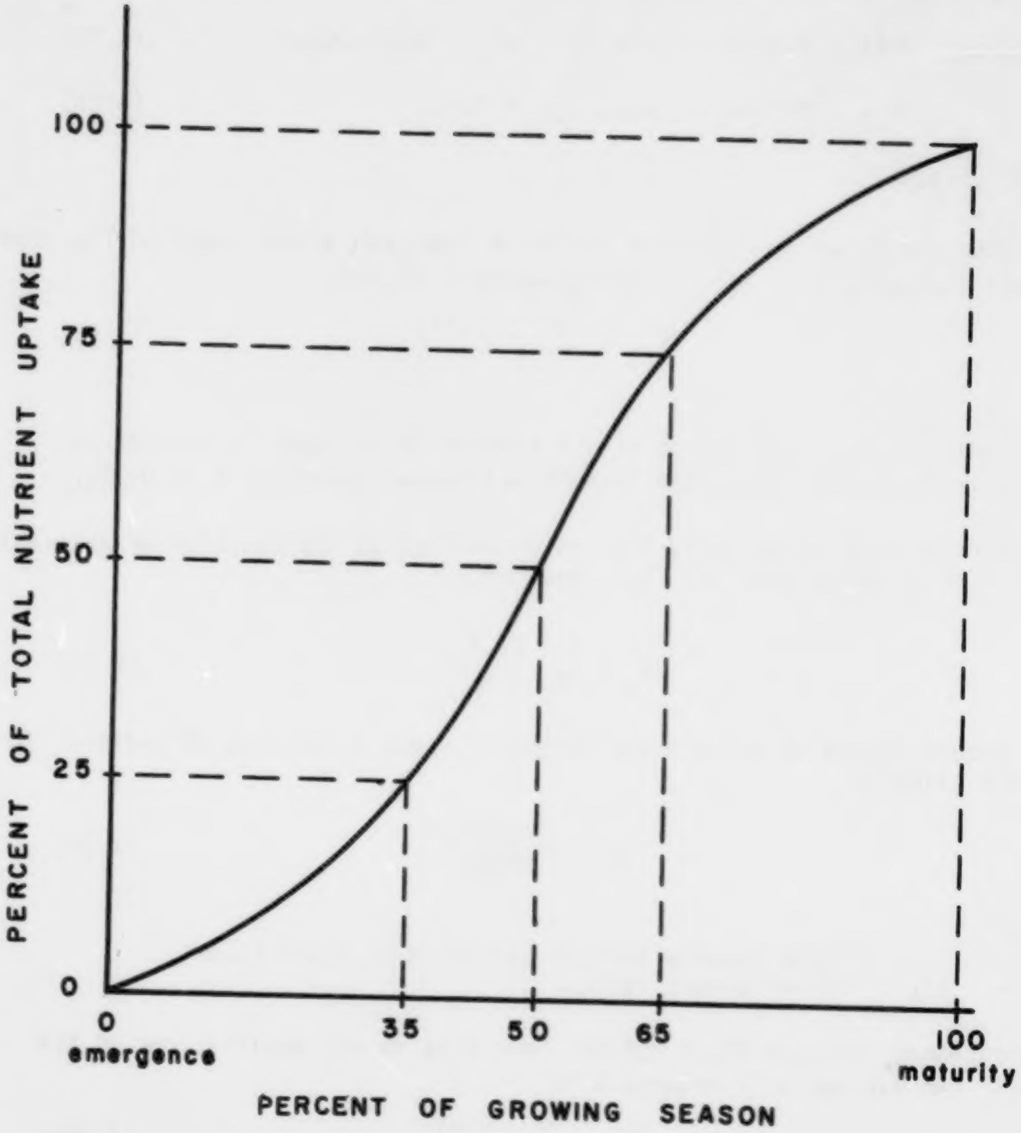
An enrichment ratio of $ER_N = 2.5$ has been used in all applications of the model. The average soil organic N is

$$\overline{O}_n = \frac{O_n + O_{n+1}}{2} \qquad (A.30)$$

Percolation Losses

Percolation losses of N are computed similarly to runoff losses and are

Figure I-6. Crop nutrient function.



based on the fraction of available water which percolates:

$$PN_{1n} = \frac{P_{1n}}{R_n + M_n + d_1\bar{\theta}_2} \bar{I}_{1n} \qquad (A.31)$$

$$PN_{2n} = \frac{P_{2n}}{P_{1n} + d_2\bar{\theta}_2} \bar{I}_{2n} \qquad (A.32)$$

Computational Sequence

Organic N levels are computed by substituting equations A.29 and A.30 into A.23 and solving for O_{n+1}. A comparable procedure is used for inorganic N. Equations A.25, A.27, A.28 and A.31 are substituted into equation A.21 which is solved for $I_{1,n+1}$. Similarly, $I_{2,n+1}$ is determined from equation A.22 using equations A.26 and A.32. These two steps may give negative $I_{1,n+1}$ and/or $I_{2,n+1}$. When this occurs, the negative values are set to zero and runof and percolation losses computed. Crop uptakes are then determined from available inorganic N minus the runoff and percolation losses.

Phosphorus

The soil P model is based on an inventory equation for available P; i.e., that small portion of total soil P which in principle is available to plants. Interactions between available and either fixed or organic P are not considered. The model is shown schematically in Figure (A)I-7. Primary concern is with P runoff losses and only the surface soil layer is modelled. The following mass balance applies in principle to the total available P. However, since most of this P is adsorbed, total available P is approximately equal to adsorbed P. Thus,

$$AP_{n+1} = AP_n + FP_n + MP_n - UP_n - QP_n - PP_n - XP_n \qquad (A.33)$$

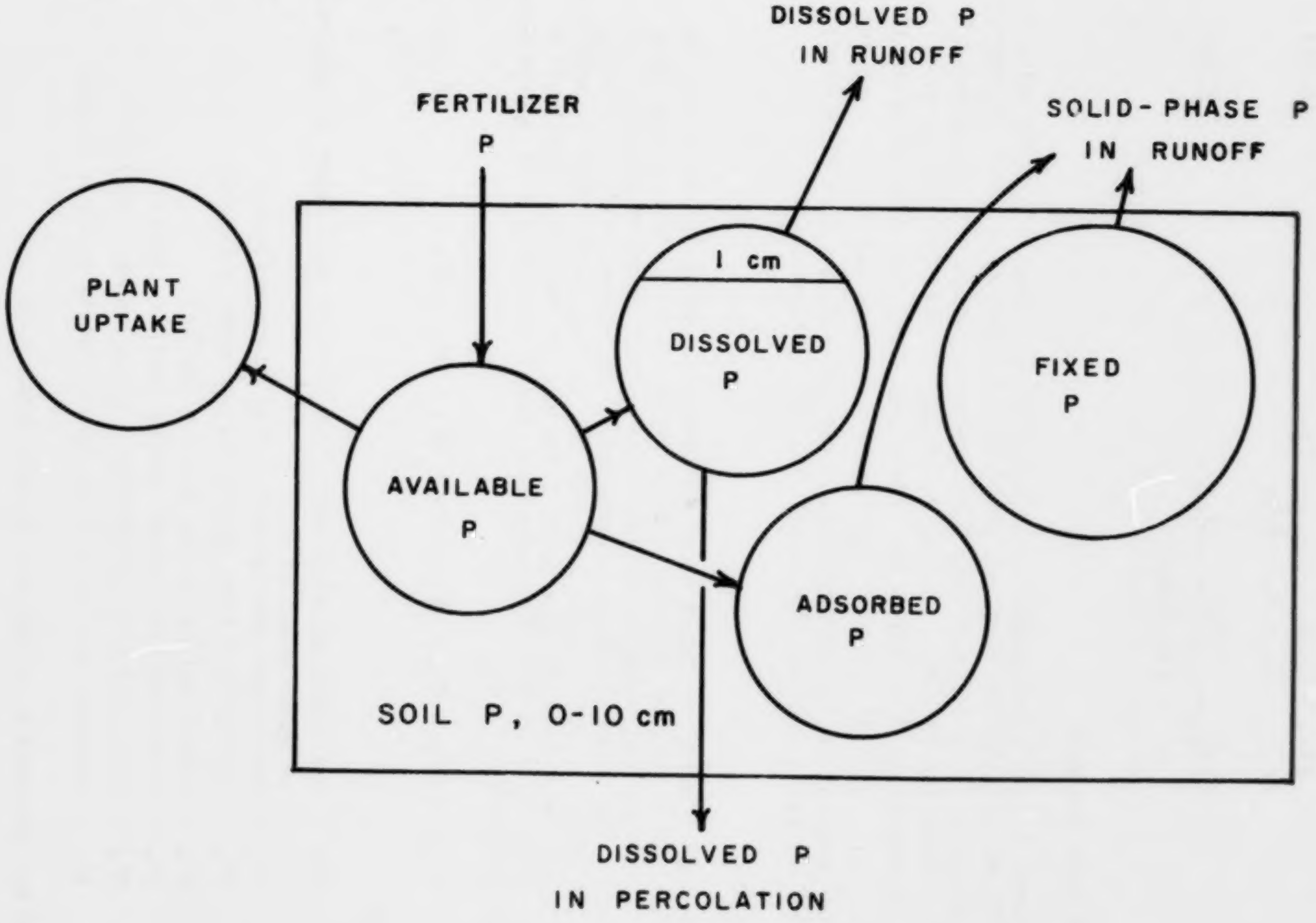
in which

AP_n = available adsorbed soil P in surface soil layer at beginning of month n (kg/ha)
FP_n = fertilizer available P during month n (kg/ha)
MP_n = available P from manure during month n (kg/ha)
UP_n = crop P uptake during month n (kg/ha)
QP_n = dissolved P in runoff during month n (kg/ha)
PP_n = dissolved P in percolation during month n (kg/ha)
XP_n = adsorbed available P in runoff during month n (kg/ha)

The average adsorbed P in the soil during month n is

$$\overline{AP} = \frac{AP_n + AP_{n+1}}{} \qquad (A.34)$$

Figure I-7. CNS phosphorus model.



As with the N model, fertilizer and manure P inputs are input parameters and the P ouput terms in equation A.33 are computed.

Crop Uptake

The sigmoid growth function from Figure (A)I-6 is used to apportion P uptake over the growing season.

Losses of Dissolved P

The concentration of dissolved P in the soil solution is determined by a linear equilibrium isotherm:

$$a_n = \beta d_n \qquad (A.35)$$

in which

a_n = average concentration of adsorbed available P in the soil during month n (mg/kg)
d_n = average concentration of dissolved available P in the soil solution during month n (mg/l)
β = P adsorption coefficient

Since the concentration a_n is $\overline{AP}_n/\rho$, the concentration of P in the soil solution is

$$d_n = \frac{\overline{AP}_n}{\beta\,\rho} \qquad (A.36)$$

The adsorption coefficient is determined by a regression equation (Haith, 1979) based on data from Enfield and Bledsoe (1975). The equaiton has % clay (%C) and pH as independent variables:

$$\beta = 5.1 + 2.2(\%C) + 26.4(pH - 6)^2 \qquad (A.37)$$

Concentration of dissolved P in runoff and percolation are assumed to be the same as that of the soil solution. However, as with the modelling of dissolved N losses in runoff, only the P in the top cm of soil is considered available for runoff losses. Hence in computing QP_n, AP_n in equation A.36 is replaced by $0.1\overline{AP}_n$, and the runoff losses converted to kg/ha are

$$QP_n = 0.01\,\frac{\overline{AP}_n}{\beta\,\rho}\,Q_n \qquad (A.38)$$

All available P in the surface layer is susceptible to percolation loss and hence

$$PP_n = 0.1\,\frac{\overline{AP}_n}{\beta\,\rho}\,P_n \qquad (A.39)$$

Losses of Solid-Phase P

As indicated in Figure (A)I-7, solid-phase runoff losses of P consist of both adsorbed and fixed P. Adsorbed losses are

$$XP_n = \frac{ER_p X_n \overline{AP}_n}{1000\rho} \qquad (A.40)$$

A P enrichment ratio of $ER_p = 2.0$ is used. Total solid phase P losses during month n, XSP_n (kg/ha) are

$$XSP_n = \frac{ER_p X_n}{1000\rho} (\overline{AP}_n + PF) \qquad (A.41)$$

where

PF = fixed P in surface layer (kg/ha).

Computational Sequence

The simulation calculations are similar to those used for N. Loss terms are substituted in equation A.33, and AP_{n+1} is computed. Runoff and percolation losses are subsequently determined based on $\overline{AP}_n$. Whenever AP_{n+1} is driven negative it is replaced with $AP_{n+1} = 0$.

VALIDATION STUDIES

The CNS model was tested using data collected in two previous field studies in Georgia and New York.

Description of Testing Sites

The Georgia sites are two small fields in Watkinsville, Ga., that were monitored for runoff, sediment and nutrient loss in runoff from May, 1974 through September, 1975. Percolation data was not collected. The two fields have predominantly well-drained Cecil sandy loam soil. Field P2 is 1.3 ha in area and had no conservation practices other than cross-slope cropping. The second field (P4) is slightly larger (1.4 ha), terraced and had a winter cover crop. More detailed descriptions of these fields and their associated management practices are given in Smith et al. (1978) and Langdale et al. (1979). Sampling and analytical procedures are described in Smith et al. (1978).

The New York testing sites are six 0.3-ha plots in Aurora, N.Y. from which runoff, percolation and nutrient loss data were collected from January, 1972 through December, 1973. Sediment data was available, but due to deposition in interceptor collection ditches it was not considered reliable. The 6 Aurora fields (A5, A8, A9, A15, A20, A21) are a sub-set of 24 plots to which manure was applied at rates of 35, 100 or 200 T/ha in either winter, spring or fall. The denitirification losses which are possible at high manure application rates are not included in the CNS model and hence **the 100 and 200 T/ha plots were not used in validations.**

The Lima and Kendaia silt loam soils at Aurora are moderately to poorly drained and are characterized by a relatively impermeable glacial till at 1-m depth. This produces slow drainage and occasional high water tables which are not adequately described in the CNS model. However 12 of the Aurora fields are tile-drained, including 6 of the 35 T/ha plots. These six plots were assumed to be reasonably consistent with the assumptions of the CNS model and were hence used for model testing.

The plots were equally divided into "poor" and "good" water management. The former (A5, A8, A15) were harvested for corn silage, hence removing all crop residues, while the latter (A9, A20, A21) were harvested for grain with the residues left on the field. Management practices, sampling and analytical techniques are described in Klausner et al. (1976a, 1976b). Drainage characteristics of the Aurora fields are also discussed by Walter et al. (1979).

Model Parameters for Validation Runs

Although the CNS model relies on standardized input data which is in principle available from secondary sources, the determination of model parameters often requires interpretation and judgement. For example, the assignment of curve numbers and crop cover factors is not straightforward even though this information is readily available in tabular form. Field conditions seldom correspond exactly with the standard descriptions given for table entries and hence assumptions and interpolations are often necessary. The model parameters used in the validation runs are given in Tables (A) I-1 through (A) I-5. The following discussion outlines data sources and any assumptions required to obtain the specific values.

Soil and Field Parameters (Table (A)I-1)

With the exception of $\overline{\theta}_j$, K, I_{jo} and m_o, all parameters for the Watkinsville fields (P2 and P4) were taken from Smith et al. (1978). The available water capacity $\overline{\theta}_j$ was obtained from the soil survey (Soil Conservation Service, 1968) and soil erodibility K was given by Barnett (1977). Bulk density ρ is the value at 15 cm, and the (LS) and P factors for the USLE are computed based on field slopes and slope lengths.

For the Aurora fields ρ, $\overline{\theta}_j$, %C and pH are all soil survey values (Soil Conservation Service, 1971). Organic N (O_o) and available P (AP_o) data were provided by S.D. Klausner, Department of Agronomy, Cornell University. Soil loss factors were not determined for Aurora since sediment and solid-phase nutrient losses were not tested for these fields.

Initial values of soil inorganic N (I_{jo}) were not based on field measurements. In both locations, the model was run from January 1, and the soil contains relatively little inorganic N at that time. The values of I_{jo}

TABLE I-1 SOIL AND FIELD PARAMETERS FOR VALIDATION WATERSHEDS

Parameter	P2	P4	A5	A8	A15	A9	A20	A21
A, Area (ha)	1.3	1.4	0.3					
ρ, bulk density (g/cm^3)	1.4	1.4	1.3					
$\overline{\theta}_j$, available water capacity (cm/cm)	0.15	0.15	0.16					
%C, percent clay	13	15	11.1					
pH	5.8	6.1	6.7					
K, soil erodability	0.28	0.28	-	-	-	-	-	-
(LS), topographic factor	0.31	0.27	-	-	-	-	-	-
P, supporting practice factor	0.6	0.5	-	-	-	-	-	-
I_{10}, initial inorganic N, layer 1, (kg/ha)	0	0	0					
I_{20}, initial inorganic N, layer 2, (kg/ha)	5	5	10					
O_o, initial organic N, layer 1 (kg/ha)	490	670	3770	2280	2830	2750	2150	2120
m_o, annual mineralization rate	0.03	0.03	0.02					
PF, fixed P (kg/ha)	260	200	-	-	-	-	-	-
AP_o, initial available P (kg/ha)	40	30	28	30	13	5	9	7

TABLE I-2. NUTRIENT APPLICATIONS AND CROP UPTAKE

	Year 1 [a] Applications					Year 2 [a] Applications				
Watershed	Inorganic N [b]	Available P [b]	Organic N in Manure	Crop Uptake N	Crop Uptake P	Inorganic N [b]	Available P [b]	Organic N in Manure	Crop Uptake N	Crop Uptake P
	kg/ha									
P2	38(5)[c] 100(6)	33(5)	-	79	17	22(4) 112(7)	31(4)	-	101	21
P4	38(5) 107(6)	33(5)	-	11 94	Rye 3 Corn 20	22(4) 112(7)	21(4)	-	11 95	Rye 3 Corn 19
A5	9(5) 25(6)	13(5) 11(6)	144(5)	73	15	2(4) 25(6)	28(4) 11(6)	158(4)	84	17
A8	34(6)	20(6)	112(6)	73	15	27(6)	37(6)	170(6)	84	17
A15	3(2) 25(6)	14(2) 11(6)	133(2)	73	15	4(1) 25(6)	19(1) 11(6)	132(1)	84	17
A9	8(5) 25(6)	13(5) 11(6)	132(5)	73	15	2(4) 25(6)	25(4) 11(6)	153(4)	84	17
A20	33(6)	20(6)	142(6)	73	15	27(6)	35(6)	156(6)	84	17
A21	4(2) 25(6)	13(2) 11(6)	102(2)	73	15	5(1) 25(6)	16(1) 11(6)	145(1)	84	17

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[a] Year 1: 1974 for P2, P4; 1972 for remainder; Year 2: 1975 for P2 and P4, 1973 for remainder

[b] Fertilizer + manure applied during month

[c] Numbers in parentheses are months of application

given in Table (A) I-1 are based on values obtained by long-term (10-25 year) CNS model runs. Hence they are roughly equivalent to long-term average or steady state values. Annual mineralization rate is the most uncertain parameter in the CNS model. The values of m_0 given in Table (A) I-1 are based on general values given by Brady (1974).

Nutrient Applications and Crop Uptake (Table (A)I-2)

Applications of nutrients were obtained directly from Smith *et al.* (1978) or Klausner *et al.* (1976a). At Aurora, based on experiments by Lauer *et al.* (1976), it was assumed that 85% of manure ammonia-N would volatilize shortly after application and hence, the inorganic N applications in Table (A) I-2 include only 15% of manure ammonia-N. Available P in manure was assumed equal to the dissolved P content. Crop nutrient uptakes at Watkinsville were estimated from yields given in Smith *et al.* (1978) while Aurora values were obtained directly from Klausner *et al* (1976a).

The organic N in manure was considered to mineralize much more rapidly than soil organic N. Based on the soil N balance given in Klausner *et al.* (1976a) for the 35 T/ha plots, a decay series of 50%-25%-10% was determined. Thus 50% of the manure organic N is mineralized during the first year following application, 25% of the remaining organic N is mineralized in the second year after application, etc. This decay series was combined with monthly temperature-dependent mineralization rates (equation A.23) to determine the manure inorganic N inputs MI_n in equation A.21.

Cropping Dates, Curve Numbers and Cover Factors (Tables (A) I-3, (A) I-4, (A) I-5)

The cropping sequences given in the tables are based on plowing, planting and harvesting dates given in Klausner *et al.* (1976a) and Smith *et al*. However, the estimated crop emergence, 100% canopy and maturity dates are guesses based on typical values for the two regions. Cover factors are linked to canopy development and were taken from Wischmeier and Smith (1978).

The CNS model is very sensitive to curve numbers and attempts were made to make the selections as objective as possible. In both locations, fallow curve numbers were used from plowing to 10% canopy. The only fields with a history of organic matter build-up were A9, A20, and A21 at Aurora and these were considered to have "good" hydrologic conditions. The remaining 5 fields were all "poor". The Watkinsville soil is in hydrologic group B, while at Aurora the groups change from plot to plot. Plots A5 and A9 are predominantly Kendaia (Group C) and Lima (Group B) is the major soil on A8, A15, A20, A21 (Jones and Zwerman, 1972). However, tile drainage artificially changes these groupings, increasing drainage and reducing runoff. Each field was thus assigned to the next lower runoff group, A for A5 and A9 and B for A8, A15, 20 and A21.

TABLE I-3 CROPPING DATES, CURVE NUMBERS AND COVER FACTORS FOR WATERSHED P2

Crop	Date	Crop Stage	% Canopy	Curve Number CN_{II}	Cover Factor C_t
	1/1/74		0	79	0.36
	4/25/74	Plow	0	86	0.61
Corn	5/3/74	Emergence	0	86	0.61
			10	79	0.51
			50	79	0.42
			80	79	0.26
	7/1/74		100	79	0.26
	9/1/74	Mature	100	79	0.26
	9/16/74	Harvest	0	79	0.36
	4/24/75	Plow	0	86	0.36
Corn	6/1/75	Emergence	0	86	0.36
			10	79	0.32
			50	79	0.29
			80	79	0.20
	7/1/75		100	79	0.20
	9/1/75	Mature	100	79	0.20
	10/3/75	Harvest	0	79	0.30

TABLE I-4 CROPPING DATES, CURVE NUMBERS AND COVER FACTORS FOR WATERSHED P4

Crop	Date	Crop Stage	% Canopy	Curve Number CN_{II}	Cover Factor C_t
Rye	1/1/74		100	72	0.05
	2/20/74	Mature	100	72	0.05
	3/24/74	Harvest	0	72	0.46
	4/23/74	Plow	0	86	0.46
Corn	5/3/74	Emergence	0	86	0.46
			10	74	0.42
			50	74	0.38
			80	74	0.22
	7/1/74		100	74	0.22
	9/1/74	Mature	100	74	0.22
	9/16/74	Harvest	0	74	0.47
Rye	11/2/74	Emergence	0	74	0.47
			10	72	0.30
			50	72	0.15
			80	72	0.05
	12/1/74		100	72	0.05
	1/21/75	Mature	100	72	0.05
	4/15/75	Harvest	0	72	0.36
	4/24/75	Plow	0	86	0.36
Corn	5/24/75	Emergence	0	86	0.36
			10	74	0.32
			50	74	0.29
			80	74	0.20
	7/1/75		100	74	0.20
	9/1/75	Mature	100	74	0.20
	9/16/75	Harvest	0	74	0.45

TABLE I-5 CROPPING DATES AND CURVE NUMBERS FOR AURORA WATERSHEDS

Date	Stage	% Canopy	Curve Numbers, CN_{II} A5	A8	A15	A9	A20	A21
1/1/72		0	86	77	77	78	67	67
5/23/72	Plow (A9, A20, A21)	0	86	77	77	86	77	77
6/19/	Emergence	0	86	77	77	86	77	77
		10	81	72	72	78	67	67
8/17/72		100	81	72	72	78	67	67
10/11/72	Mature	100	81	72	72	78	67	67
10/26/72	Harvest	0	81	72	72	78	67	67
10/26/72	Plow (A5, A8, A15)	0	86	77	77	78	67	67
4/25/73	Plow (A9, A20, A21)	0	86	77	77	86	77	77
6/12/73	Emergence	0	86	77	77	86	77	77
		10	81	72	72	78	67	67
8/11/73		100	81	72	72	78	67	67
10/15/73	Mature	100	81	72	72	78	67	67
10/29/73	Harvest	0	81	72	72	78	67	67
10/29/73	Plow (A5, A8, A15)	0	86	77	77	78	67	67

Validation Results

Watkinsville, Ga. Sites

Measured nutrient, water and sediment losses are compared with CNS model predictions for the 17-mo period May 1974 through September, 1975 in Table (A) I-6. Precipitation during this time was 123 cm on field P2 and 97 cm on field P4. Observed losses were taken from Smith et al. (1978). Runoff predictions exceed observations by substantial amounts on both fields, although errors were smaller on P4. Dissolved N and P are over-predicted by approximately the same degree as runoff on P2, indicating that errors in these predictions are more likely due to faulty hydrologic parameters than serious errors in nutrient balances. Sediment and solid-phase nutrient predictions are quite reasonable, particularly considering the crude and somewhat arbitrary nature of model predictive equations and parameters for these losses.

The most critical problem is in the simulated losses of dissolved P in runoff. Although the magnitudes of these losses approximate the observations, the large predicted reduction from P2 to P4 was not seen in observations. As indicated in Table (A) I-7, this was the only substantial difference in losses between the two fields that was not accounted for by the model. The probable sources of error is the absence of a source term in the CNS model for leaching of P from plant material during the colder months. January, February and March accounted for 56% of the observed dissolved P loss from P4 which had a rye winter cover crop. The comparable figure for P2, which had no winter plant cover, was 29%.

Aurora, N.Y. Sites

The six New York fields are far from ideal as a basis for model testing. Not only are the sites artificially drained, but the primary nutrient sources are manure applications. The CNS model is not well-suited for either of these characteristics. Nevertheless, the Aurora validation studies were considered essential since the Georgia simulations provided no testing of either the percolation or snowmelt portions of the CNS model. The two-year testing period at Aurora had 189 cm of precipitation, 14% of which fell in June, 1972, when Hurricane Agnes passed over the sites.

Observed and predicted losses for the six New York fields are shown in Table (A) I-8. Observed values were provided by S.D. Klausner. Examination of percolation observations revealed another problem with these sites. Percolation was improbably high on two of the fields (A5 and A9) suggesting that water flows were not independent. For this reason, comparisons of the mean losses shown in Table (A) I-8 are more relevant than comparisons of the separate fields. On this basis, runoff and percolation predictions are relatively accurate. Dissolved N in runoff is underpredicted, indicating that more manure N was available for runoff than had been estimated for model input values. Observed dissolved P losses were nearly an order of magnitude greater than predictions. The CNS model assumed that manure available P can be described by the same equilibrium relationships as P in the soil. The assumption appears to be untenable. The overprediction of dissolved N in

TABLE I-6 COMPARISON OF CNS MODEL PREDICTIONS WITH OBSERVED RUNOFF, SEDIMENT AND NUTRIENT LOSSES FOR GEORGIA SITES (May, 1974-September, 1975)

	Field P2		Field P4	
	Observed	Predicted	Observed	Predicted
Runoff (cm)	28.0	40.2	19.7	23.3
Sediment (T/ha)	7.3	9.5	1.9	1.6
Dissolved N in Runoff (kg/ha)	3.6[a]	5.6	2.0[a]	2.4
Solid-phase N in Runoff (kg/ha)	9.4[b]	8.2	3.5[b]	2.1
Dissolved P in Runoff (kg/ha)	0.31[c]	0.46	0.34[c]	0.19
Solid-phase P in Runoff (kg/ha)	5.8[d]	4.5	1.6[d]	0.6

[a] NO_3-N + NH_4-N in solution

[b] TKN in sediment

[c] PO_4-P

[d] Total P in sediment

TABLE I-7 COMPARISON OF OBSERVED AND PREDICTED VARIATIONS BETWEEN FIELDS P2 and P4

	Percent Change from P2 to P4	
	Observed	Predicted
Runoff	-30	-42
Sediment	-74	-83
Dissolved N in Runoff	-44	-57
Solid-phase N in Runoff	-63	-74
Dissolved P in Runoff	+10	-59
Solid-phase P in Runoff	-72	-87

TABLE I-8 COMPARISON OF CNS MODEL PREDICTIONS WITH OBSERVED RUNOFF, PERCOLATION AND DISSOLVED NUTRIENT LOSSES FOR NEW YORK SITES (January, 1972-December, 1973)

	Runoff (cm)		Percolation (cm)		Dissolved N in Runoff (kg/ha)		Dissolved P in Runoff (kg/ha)		Dissolved N in Percolation (kg/ha)	
Field	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
A5	25.4	35.6	166.9	64.9	8.0	7.2	0.63	0.26	118.2	154.1
A8	7.9	17.6	21.1	82.8	0.9	1.4	0.45	0.10	27.2	98.9
A15	15.5	17.6	24.9	82.8	7.0	2.0	1.43	0.07	29.8	127.2
A9	15.3	24.7	145.0	76.1	3.1	3.7	0.24	0.08	120.8	125.2
A20	23.5	10.6	53.0	89.8	12.6	1.0	1.17	0.02	49.6	106.2
A21	8.3	10.6	85.0	89.8	5.1	0.8	0.95	0.03	111.2	98.1
Mean	19.2	23.3	99.2	97.2	7.3	3.2	0.97	0.11	91.4	141.9

percolation is not as serious as it may appear. Measured N losses are based on tile drainage at 100-cm depths, while predicted values are for percolation from the top 30 cm of soil. Additional N losses due to plant uptake and denitrification are likely in the downward movement of N to the 100 cm depth. Also, this movement is not instantaneous, and substantial amounts of inorganic N will have remained in the soil profile between 30 and 100 cm.

Validation Summary

The credibility of a mathematical simulation model is largely subjective. No model is a complete picture of reality. Rather, models are sets of hypotheses concerning the fundamental aspects of physical and biochemical phenomena. Given the unavoidable errors in data collection and analysis as well as the judgement required in estimating model parameters, models cannot be proven to be correct. Comparison of model predictions with field measurement can however, provide some indication of consistency and accuracy. **Based on these validation studies, the CNS model appears to be a reasonable means of estimating nutrient losses from croplands. It accounts for differences in crop, soil and weather characteristics and reflects the impacts of management practices such as runoff and erosion control and fertilizer applications. However, the model is not a satisfactory means for estimating the effects of manure management. Neither is it useful in comparing dissolved P losses from fields with substantially different plant covers.**

APPENDIX II

GENERATION OF DAILY PRECIPITATION AND TEMPERATURE FOR THE CNS MODEL

The daily precipitation and temperature models are independent lag one Markov processes, fitted to the meterologic characteristics of the area being modelled. The precipitation model utilizes a binary distribution to determine whether precipitation is greater than a threshold value (.025 cm). The binary distribution is fitted to the average number of days in each month with rain, and is affected by whether the previous day was dry or wet. The conditional probability of rain on day t was computed from the unconditional probability by use of a regression equation presented by Hershfield (1970). The amount of precipitation on a day is predicted using an exponential distribution, fitted to best approximate the mean monthly precipitation. The model was found to slightly underpredict the number of large storms as compared to historic data.

The temperatures model includes the effects of seasonal and local variations in average air temperature. Temperature on day t is a function of the expected mean temperature on day t, the temperature on the preceding day, and a random noise term. From inspection of historic records, it was found that the correlation of the previous day's temperature with the current day is roughly constant over time and location, and that the variation in the random noise term may be approximated by a function of mean temperature.

Precipitation Model

Define a wet day as $Pr_t \geq .025$ cm
(if $Pr_t < .025$ cm, the $Pr_t = 0$)

then $P_n(W)$ = unconditional probability of rain on any day in month n = (# days with $Pr_t > .025$ cm)/(# days in month)

$P_n(D)$ = unconditional probability of no rain on any day in month n = $1 - P_n(W)$

$P_n(D/D)$ = conditional probability of a dry day following a dry day in month n = $.1718 + .8462\, P_n(D)$(Hershfield, 1970)

then $P_n(W/D) = 1 - P_n(D/D)$

and $P_n(D/W) = P_n(D) \cdot P_n(W/D)/P_n(W)$
(this is due to the equal number of W-D and D-W sequences in any long record)

$P_n(W/W) = 1 - P_n(D/W)$

Finally, define θ_n = average daily precipitation on days with rain in month n (cm)
= (av. monthly precip.)/(# days with rain)

To generate a value for Pr_t on any day, choose two independent uniform 0 - 1 variates X_t and Y_t; then

if $[X_t < P_n(W/D)$ and $Pr_{t-1} < .025$ cm$]$

or $[X_t < P_n(W/W)$ and $Pr_{t-1} \geq .025$ cm$]$

then $Pr_t = .025 - \theta_n \ln (Y_t)$
else $Pr_t = 0$

Temperature model

define:
T_t = average air temperature on day t (°C)
μ_t = expected value of T_t on day t (°C)
ζ_t = correlation of temperature on day t-1 with temperature on day t (dmless)
σ_t^2 = variance of temperature expected on day t (°C)
V_t = random normal variable of mean 0 and variance 1; may be generated from uniform 0-1 variates by
$V_t = (-2 \ln X_t)^{1/2} \cos(2\pi Y_t)$

then

$$T_t = \mu_t + \zeta_t (T_{t-1} - \mu_{t-1}) + V_t \sigma_t (1 - \zeta_t^2)^{1/2}$$

By inspection of historic records,

a) μ_t varies sinusoidally over the year, and may be described by

$$\mu_t = \bar{T} + TD \sin (.01745 (J_t - 105))$$

where
$\bar{T}$ = average yearly temperature (°C)
TD = (average July temperature) - $\bar{T}$ (°C)
J_t = julian date of day t

b) ζ_t ranges from .60 to .70 for most seasons and locations, and is therefore fixed at .65

c) σ_t varies consistently with μ_t, such that

$$\sigma_t^2 = 33.412 - 1.169\ \mu_t$$

from analysis of twenty-five year records at Ames, Iowa, Aurora, N.Y., and Athens, Ga.

The data necessary to implement the meteorologic model is then average precipitation and number of days with precipitation by month, and average summer and annual air temperatures, as given in Section 2.

APPENDIX III

RUNOFF, PERCOLATION, AND DISSOLVED NUTRIENT PREDICTIVE EQUATION COEFFIENTS

The tables in this appendix are arranged first by crop, secondly by timing of tillage, and lastly by soil hydrologic group. Within each of these categories, predictive equation coefficients are first presented for runoff and percolation (a, b, a', and b') for each geographic region modelled, followed by coefficients for the nutrient concentration equations (a_i, b_i, and c_i) for spring or fall fertilizer applications. The following index may aid in the quick location of a specific table:

Crop	Regions modelled	Tillage type	Soil hydro-logic group	Table of coefficients for runoff and percolation	Timing of fertilizer application	Table of coefficients for dissolved nutrient concentrations
corn	all 27	no tillage	A,B,C,D	C-1	spring	C-2
					fall	C-3
		fall plow	A	C-4	spring	C-5
					fall	C-6
			B	C-7	spring	C-8
					fall	C-9
			C	C-10	spring	C-11
					fall	C-12
			D	C-13	spring	C-14
					fall	C-15
		spring plow	A,B	C-16	spring	C-17
					fall	C-18
			C,D	C-19	spring	C-20
					fall	C-21
hay	1-8,12 16-19,22-26	no tillage	A,B,C,D	C-22	spring	C-23
					fall	C-24
soybeans	1-21,25-27	no tillage	A,B,C,D	C-25	spring	C-26
					fall	C-27
		fall plow	A	C-28	spring	C-29
					fall	C-30
			B	C-31	spring	C-32
					fall	C-33
			C	C-34	spring	C-35
					fall	C-36
			D	C-37	spring	C-38
					fall	C-39
		spring plow	A,B	C-40	spring	C-41
					fall	C-42
			C,D	C-43	spring	C-44
					fall	C-45
corn with winter cover	1,2,6-13, 16-20,22, 25,26	no tillage	A,B,C,D	C-46	spring	C-47
					fall	C-48

TABLE (A)III-1. CORN, NO TILLAGE (A,B,C,D SOILS)

REGION	AW	A	B	A	B	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	2.23	-5.16	-2.17	53.94	10	5	2.96	-5.81	-2.88	60.53	19	5	4.07	-7.48	-4.05	75.60
	10	2.13	-4.99	-2.02	42.04		10	2.87	-5.64	-2.60	45.94		10	4.07	-7.61	-3.98	68.52
	15	2.03	-4.79	-1.87	33.04		15	2.72	-5.36	-2.40	36.69		15	4.01	-7.56	-3.88	63.40
	20	1.92	-4.52	-1.76	25.19		20	2.60	-5.07	-2.22	28.98		20	3.97	-7.59	-3.83	59.28
2	5	3.01	-6.09	-2.97	60.09	11	5	3.52	-6.95	-3.47	69.90	20	5	4.15	-7.37	-4.13	76.09
	10	2.93	-5.96	-2.83	49.70		10	3.42	-6.77	-3.22	57.13		10	4.15	-7.47	-4.04	67.49
	15	2.84	-5.82	-2.70	42.08		15	3.36	-6.76	-3.04	48.97		15	4.12	-7.51	-3.94	61.60
	20	2.74	-5.56	-2.59	36.28		20	3.28	-6.66	-2.90	42.32		20	4.06	-7.49	-3.81	56.60
3	5	3.88	-6.81	-3.87	74.88	12	5	3.83	-7.11	-3.80	74.23	21	5	4.38	-7.08	-4.35	76.92
	10	3.91	-7.02	-3.89	69.33		10	3.87	-7.26	-3.78	65.82		10	4.40	-7.22	-4.31	68.63
	15	3.89	-7.01	-3.89	66.04		15	3.89	-7.36	-3.73	60.06		15	4.37	-7.29	-4.23	62.89
	20	3.87	-7.04	-3.86	63.28		20	3.86	-7.46	-3.64	55.28		20	4.32	-7.28	-4.15	58.41
4	5	3.36	-6.99	-3.33	66.36	13	5	4.50	-7.09	-4.46	78.80	22	5	3.83	-7.44	-3.83	77.79
	10	3.38	-7.19	-3.28	56.86		10	4.47	-7.05	-4.33	70.11		10	3.85	-7.66	-3.83	72.31
	15	3.32	-7.15	-3.16	50.04		15	4.43	-7.07	-4.18	64.15		15	3.83	-7.63	-3.83	68.82
	20	3.26	-7.11	-3.13	44.82		20	4.39	-7.12	-4.06	59.38		20	3.81	-7.65	-3.81	65.90
5	5	3.56	-6.93	-3.54	69.50	14	5	4.40	-6.94	-4.36	76.96	23	5	4.77	-6.72	-4.76	84.31
	10	3.58	-7.05	-3.51	61.74		10	4.40	-7.07	-4.23	68.10		10	4.79	-6.85	-4.77	79.94
	15	3.55	-7.06	-3.48	56.40		15	4.36	-7.10	-4.11	62.21		15	4.79	-6.87	-4.79	77.05
	20	3.52	-7.02	-3.44	51.93		20	4.29	-7.14	-3.98	57.47		20	4.78	-6.87	-4.77	74.57
6	5	2.10	-4.70	-2.00	48.79	15	5	4.49	-6.49	-4.47	75.86	24	5	3.94	-7.36	-3.93	76.50
	10	2.01	-4.69	-1.75	34.62		10	4.52	-6.78	-4.45	68.08		10	3.95	-7.56	-3.91	70.25
	15	1.90	-4.49	-1.54	25.75		15	4.51	-6.92	-4.44	63.33		15	3.93	-7.57	-3.90	66.23
	20	1.79	-4.25	-1.41	19.11		20	4.49	-6.96	-4.42	59.62		20	3.89	-7.52	-3.87	62.90
7	5	2.68	-5.70	-2.61	57.56	16	5	3.55	-6.72	-3.53	72.58	25	5	4.16	-8.01	-4.14	79.18
	10	2.70	-5.91	-2.47	44.34		10	3.52	-6.85	-3.45	65.22		10	4.17	-8.04	-4.12	71.69
	15	2.63	-5.91	-2.24	35.40		15	3.48	-6.79	-3.37	59.71		15	4.16	-8.07	-4.10	66.50
	20	2.56	-5.78	-2.05	28.30		20	3.45	-6.81	-3.36	55.67		20	4.13	-8.06	-4.07	62.37
8	5	3.65	-6.96	-3.61	71.26	17	5	3.72	-7.26	-3.71	74.36	26	5	4.03	-6.52	-4.01	74.21
	10	3.70	-7.21	-3.61	63.29		10	3.74	-7.46	-3.68	67.41		10	4.09	-6.82	-4.04	65.96
	15	3.70	-7.28	-3.56	57.78		15	3.70	-7.42	-3.63	62.35		15	4.11	-7.07	-4.06	61.29
	20	3.67	-7.35	-3.53	53.54		20	3.67	-7.40	-3.59	57.94		20	4.10	-7.06	-4.05	57.58
9	5	2.35	-4.96	-2.23	48.95	18	5	4.25	-7.91	-4.24	79.99	27	5	3.91	-6.56	-3.89	68.88
	10	2.19	-4.72	-1.83	33.09		10	4.24	-8.03	-4.20	73.49		10	3.96	-6.83	-3.91	59.98
	15	2.08	-4.52	-1.69	24.50		15	4.18	-7.97	-4.13	68.62		15	4.00	-7.13	-3.89	54.36
	20	1.97	-4.26	-1.45	17.51		20	4.14	-7.97	-4.09	64.52		20	4.00	-7.30	-3.87	50.03

TABLE (A)III-2. CORN, NO TILLAGE, SPRING FERTILIZATION (A,B,C,D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.18	-0.11	2.26	0.31	0.23	0.06	-12.0	-0.8	36.6	8.0	2.5	0.6	-1.71	-0.03	0.71	1.16	-0.01	0.00
	10	-0.54	-0.19	2.31	0.40	0.51	0.12	-14.3	-1.3	43.7	9.6	3.9	0.9	-1.69	-0.03	0.58	1.17	0.01	0.00
	15	-1.03	-0.26	2.55	0.61	0.85	0.18	-16.7	-2.2	51.0	11.3	6.6	1.5	-1.90	-0.00	0.47	1.17	0.02	0.00
	20	-1.45	-0.37	3.77	0.86	1.21	0.25	-18.9	-4.2	57.1	12.6	12.9	2.9	-1.95	0.00	0.49	1.17	0.01	0.00
2	5	-0.13	-0.10	0.36	0.13	0.29	0.05	-9.1	-1.0	27.6	5.1	3.0	0.5	-0.44	-0.19	0.16	1.17	0.04	-0.00
	10	-0.43	-0.15	0.50	0.22	0.49	0.08	-10.2	-1.4	31.1	5.7	4.5	0.8	-0.31	-0.20	0.09	1.17	0.05	-0.00
	15	-0.82	-0.19	0.85	0.35	0.70	0.11	-10.8	-2.2	33.5	6.1	6.7	1.3	-0.04	-0.23	0.02	1.17	0.05	-0.00
	20	-1.16	-0.23	1.71	0.53	0.89	0.14	-11.0	-3.2	33.9	6.2	9.8	1.8	-0.09	-0.22	0.03	1.17	0.05	0.00
3	5	-0.06	-0.06	0.32	0.04	0.16	0.03	-4.8	-0.9	13.1	2.0	1.7	0.3	-1.90	-0.27	0.28	1.15	0.03	0.00
	10	-0.02	-0.11	0.10	0.04	0.26	0.04	-5.3	-1.3	13.8	2.1	2.2	0.3	-1.68	-0.30	0.22	1.16	0.04	0.00
	15	0.00	-0.16	0.01	0.04	0.35	0.05	-6.1	-1.5	14.5	2.2	2.4	0.4	-1.67	-0.31	0.21	1.16	0.04	0.00
	20	0.05	-0.21	-0.17	0.03	0.45	0.06	-6.9	-1.7	15.1	2.3	2.6	0.4	-1.55	-0.33	0.17	1.16	0.04	0.00
4	5	-0.40	-0.06	1.67	0.24	0.09	0.03	-7.7	-1.3	18.0	4.0	2.2	0.5	-5.07	-0.06	0.86	1.14	-0.01	0.00
	10	-0.40	-0.14	1.71	0.26	0.22	0.06	-9.2	-2.2	20.1	4.4	3.2	0.7	-4.70	-0.10	0.79	1.15	-0.01	0.00
	15	-0.38	-0.23	1.60	0.28	0.37	0.09	-11.2	-2.9	21.9	4.7	4.3	0.9	-4.78	-0.10	0.75	1.15	-0.00	0.00
	20	-0.40	-0.35	1.58	0.31	0.56	0.12	-12.2	-3.8	22.3	4.8	6.0	1.3	-4.78	-0.10	0.71	1.16	0.00	0.00
5	5	-0.06	-0.08	0.48	0.07	0.14	0.04	-7.0	-1.1	14.2	3.2	1.8	0.4	-4.15	-0.36	0.38	1.15	0.03	0.00
	10	-0.03	-0.14	0.31	0.08	0.26	0.06	-7.9	-1.7	15.5	3.4	2.4	0.5	-3.89	-0.39	0.34	1.16	0.03	0.00
	15	0.02	-0.22	0.12	0.08	0.37	0.08	-8.8	-2.3	16.2	3.6	3.2	0.7	-3.74	-0.42	0.30	1.16	0.04	0.00
	20	-0.00	-0.29	0.04	0.09	0.51	0.10	-9.7	-2.9	16.8	3.6	4.0	0.9	-3.93	-0.42	0.29	1.16	0.04	0.00
6	5	-0.66	-0.08	2.14	0.41	0.22	0.05	-18.2	-1.9	37.2	9.4	2.8	0.7	-8.27	0.16	1.12	1.15	-0.02	0.00
	10	-0.34	-0.28	3.04	0.35	0.37	0.13	-27.5	-3.9	50.0	12.4	5.5	1.4	-5.94	-0.07	1.06	1.16	-0.02	0.00
	15	-0.24	-0.55	2.92	0.32	0.77	0.23	-36.4	-7.0	61.7	15.2	9.8	2.4	-5.74	-0.08	1.02	1.16	-0.01	0.00
	20	0.18	-0.96	3.25	0.24	1.26	0.36	-43.8	-12.6	71.3	17.5	18.1	4.5	-3.71	-0.27	0.99	1.17	-0.01	0.00
7	5	-0.55	-0.06	1.20	0.40	0.17	0.04	-10.1	-1.4	21.5	6.5	2.1	0.6	-8.23	0.04	1.07	1.15	-0.01	0.00
	10	-0.63	-0.15	1.66	0.49	0.26	0.08	-13.6	-2.8	26.4	7.8	3.9	1.1	-7.54	-0.04	1.06	1.15	-0.01	0.00
	15	-0.88	-0.28	2.19	0.67	0.43	0.12	-17.2	-4.5	30.9	9.0	6.2	1.8	-7.38	-0.06	1.02	1.16	-0.01	0.00
	20	-1.19	-0.46	2.85	0.83	0.67	0.19	-19.7	-7.3	33.2	9.6	10.3	3.0	-7.24	-0.08	1.01	1.16	-0.01	0.00
8	5	-0.28	-0.05	0.94	0.18	0.07	0.03	-6.5	-1.0	11.4	3.1	1.4	0.4	-11.01	0.21	0.84	1.12	-0.02	0.00
	10	-0.34	-0.10	0.93	0.22	0.15	0.04	-7.2	-1.5	12.3	3.3	1.9	0.5	-11.04	0.21	0.81	1.13	-0.01	0.00
	15	-0.38	-0.16	0.94	0.25	0.24	0.06	-7.8	-1.9	13.0	3.4	2.5	0.7	-11.02	0.19	0.80	1.13	-0.01	0.00
	20	-0.45	-0.22	0.88	0.28	0.34	0.08	-8.2	-2.4	13.4	3.5	3.0	0.8	-11.55	0.23	0.78	1.13	-0.01	0.00
9	5	-0.64	-0.16	0.94	0.36	0.27	0.10	-24.9	-2.8	33.3	12.6	3.2	1.2	-25.92	0.75	1.17	1.14	-0.02	0.00
	10	-0.72	-0.35	0.80	0.43	0.50	0.17	-37.8	-5.7	47.0	17.3	6.4	2.3	-27.06	0.88	1.20	1.14	-0.02	0.00
	15	-0.90	-0.68	0.50	0.51	0.92	0.31	-47.0	-10.7	56.5	20.7	12.0	4.3	-28.23	0.96	1.20	1.15	-0.02	0.00
	20	-0.78	-1.26	0.37	0.46	1.56	0.53	-66.9	-12.6	76.8	28.1	14.8	5.1	-28.17	0.91	1.20	1.15	-0.02	0.00

TABLE (A)III-2 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.35	-0.10	0.53	0.36	0.21	0.07	-14.6	-1.9	20.1	9.0	2.1	0.9	-25.87	0.92	1.12	1.12	-0.02	0.00
	10	-0.52	-0.22	0.67	0.47	0.31	0.12	-19.2	-3.7	25.0	11.1	4.0	1.7	-25.65	0.92	1.14	1.13	-0.02	0.00
	15	-0.58	-0.39	0.54	0.48	0.53	0.21	-22.5	-6.4	28.4	12.3	6.8	2.9	-25.84	0.94	1.14	1.14	-0.02	0.00
	20	-0.64	-0.68	0.54	0.49	0.86	0.34	-21.9	-11.9	27.6	11.8	12.6	5.3	-25.64	0.91	1.15	1.15	-0.02	0.00
11	5	-0.27	-0.07	0.97	0.35	0.08	0.05	-8.4	-1.2	12.2	6.1	1.4	0.7	-17.84	0.41	0.99	1.11	-0.02	0.00
	10	-0.40	-0.12	1.15	0.44	0.13	0.08	-10.5	-2.1	14.5	7.1	2.3	1.1	-17.23	0.38	0.99	1.12	-0.02	0.00
	15	-0.42	-0.21	1.13	0.49	0.24	0.12	-12.0	-3.1	16.1	7.7	3.3	1.5	-16.94	0.35	0.99	1.13	-0.02	0.00
	20	-0.48	-0.34	1.11	0.54	0.40	0.17	-13.0	-4.4	17.1	8.1	4.6	2.2	-17.38	0.39	1.00	1.13	-0.02	0.00
12	5	-0.20	-0.04	0.73	0.21	0.09	0.03	-4.2	-0.8	9.7	3.2	1.2	0.4	-9.45	0.17	0.94	1.11	-0.01	0.00
	10	-0.24	-0.07	0.79	0.24	0.14	0.04	-4.5	-1.3	10.4	3.4	1.8	0.5	-9.66	0.18	0.94	1.11	-0.01	0.00
	15	-0.29	-0.12	0.80	0.28	0.21	0.06	-5.0	-1.7	11.0	3.5	2.3	0.7	-9.83	0.19	0.93	1.12	-0.01	0.00
	20	-0.31	-0.17	0.79	0.30	0.29	0.08	-5.7	-2.1	11.6	3.6	2.7	0.9	-9.99	0.19	0.92	1.12	-0.01	0.00
13	5	-0.14	-0.04	0.42	0.21	0.07	0.03	-3.7	-0.9	6.9	3.1	1.2	0.5	-12.93	0.34	0.81	1.09	-0.01	0.01
	10	-0.20	-0.07	0.48	0.25	0.11	0.05	-4.2	-1.3	7.5	3.2	1.7	0.7	-12.85	0.33	0.82	1.09	-0.01	0.01
	15	-0.21	-0.12	0.46	0.28	0.17	0.06	-4.6	-1.7	8.0	3.4	2.0	0.8	-12.78	0.33	0.82	1.10	-0.01	0.01
	20	-0.20	-0.17	0.43	0.29	0.25	0.09	-5.1	-1.9	8.4	3.5	2.3	0.9	-12.85	0.34	0.81	1.11	-0.01	0.00
14	5	-0.13	-0.04	0.29	0.20	0.07	0.03	-4.0	-0.9	6.9	3.2	1.2	0.5	-13.51	0.35	0.72	1.09	-0.01	0.01
	10	-0.17	-0.08	0.32	0.24	0.12	0.05	-4.5	-1.4	7.4	3.4	1.7	0.7	-13.51	0.35	0.72	1.09	-0.01	0.01
	15	-0.18	-0.13	0.28	0.26	0.19	0.07	-4.9	-1.8	7.9	3.5	2.0	0.9	-13.32	0.33	0.70	1.10	-0.01	0.01
	20	-0.16	-0.19	0.20	0.27	0.27	0.09	-5.3	-2.1	8.3	3.6	2.4	1.0	-13.20	0.32	0.68	1.11	-0.01	0.00
15	5	-0.11	-0.04	0.38	0.20	0.06	0.04	-2.5	-0.8	5.4	2.8	1.1	0.5	-10.54	0.11	0.72	1.07	-0.00	0.01
	10	-0.11	-0.07	0.38	0.21	0.10	0.05	-2.6	-1.3	5.5	2.9	1.6	0.7	-10.39	0.09	0.72	1.08	0.00	0.01
	15	-0.09	-0.11	0.36	0.22	0.15	0.07	-2.5	-1.7	5.4	2.7	2.0	0.9	-10.08	0.05	0.70	1.09	0.00	0.01
	20	-0.05	-0.16	0.33	0.21	0.21	0.09	-2.4	-2.1	5.1	2.6	2.5	1.2	-9.98	0.04	0.70	1.10	0.00	0.01
16	5	-0.09	-0.06	1.36	0.14	0.05	0.03	-6.0	-0.9	12.8	3.1	1.4	0.3	-5.45	-0.23	0.64	1.14	-0.00	0.00
	10	-0.05	-0.12	1.16	0.13	0.14	0.05	-7.4	-1.3	14.2	3.4	1.8	0.4	-5.15	-0.27	0.58	1.14	0.01	0.00
	15	-0.09	-0.18	1.16	0.16	0.24	0.06	-8.9	-1.6	15.6	3.6	2.2	0.5	-5.19	-0.27	0.57	1.15	0.01	0.00
	20	-0.20	-0.23	1.02	0.19	0.35	0.08	-9.9	-1.9	16.4	3.8	2.6	0.6	-5.54	-0.26	0.53	1.15	0.01	0.00
17	5	-0.16	-0.06	0.48	0.12	0.10	0.03	-5.8	-0.9	10.4	2.7	1.2	0.3	-10.02	0.03	0.58	1.13	0.00	0.00
	10	-0.16	-0.11	0.40	0.13	0.18	0.05	-6.6	-1.2	11.3	2.9	1.6	0.4	-9.46	-0.04	0.51	1.14	0.01	0.00
	15	-0.27	-0.16	0.26	0.17	0.27	0.06	-7.4	-1.5	12.1	3.1	1.9	0.5	-9.80	-0.03	0.49	1.14	0.01	0.00
	20	-0.40	-0.21	0.27	0.21	0.36	0.07	-8.3	-1.8	12.8	3.2	2.2	0.6	-10.11	-0.01	0.48	1.14	0.01	0.00
18	5	-0.15	-0.05	0.40	0.14	0.08	0.02	-4.0	-0.8	7.3	2.4	1.0	0.3	-13.72	0.32	0.68	1.10	-0.01	0.00
	10	-0.18	-0.08	0.37	0.16	0.13	0.04	-4.4	-1.1	7.6	2.5	1.3	0.4	-13.61	0.32	0.65	1.11	-0.00	0.00
	15	-0.25	-0.12	0.34	0.19	0.18	0.05	-5.1	-1.3	8.2	2.6	1.5	0.5	-13.67	0.32	0.63	1.11	-0.00	0.00
	20	-0.32	-0.15	0.21	0.21	0.26	0.06	-5.7	-1.5	8.6	2.7	1.7	0.5	-13.88	0.34	0.61	1.12	-0.00	0.00

TABLE (A)III-2 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.20	-0.05	0.30	0.19	0.08	0.03	-4.9	-0.9	7.6	2.9	1.1	0.4	-15.29	0.47	0.72	1.10	-0.01	0.00
	10	-0.27	-0.09	0.22	0.22	0.14	0.04	-5.4	-1.2	8.2	3.1	1.4	0.5	-15.85	0.52	0.70	1.10	-0.01	0.00
	15	-0.36	-0.13	0.21	0.26	0.20	0.06	-6.1	-1.5	8.8	3.3	1.6	0.6	-15.98	0.53	0.70	1.11	-0.01	0.00
	20	-0.44	-0.17	0.19	0.29	0.27	0.07	-6.6	-1.7	9.2	3.4	1.9	0.7	-16.05	0.53	0.67	1.11	-0.01	0.00
20	5	-0.12	-0.04	0.38	0.19	0.08	0.03	-3.9	-0.9	7.7	3.2	1.2	0.5	-11.10	0.22	0.68	1.10	-0.00	0.00
	10	-0.13	-0.08	0.42	0.23	0.13	0.05	-4.6	-1.3	8.3	3.4	1.6	0.6	-10.99	0.21	0.66	1.11	-0.00	0.00
	15	-0.12	-0.13	0.35	0.24	0.20	0.07	-5.1	-1.7	8.9	3.6	2.0	0.8	-10.79	0.19	0.64	1.11	-0.00	0.00
	20	-0.15	-0.19	0.28	0.27	0.28	0.09	-5.7	-2.1	9.5	3.7	2.4	0.9	-10.86	0.19	0.62	1.12	0.00	0.00
21	5	-0.12	-0.04	0.34	0.19	0.07	0.03	-3.2	-0.8	6.5	3.0	1.1	0.5	-9.92	0.18	0.69	1.09	-0.00	0.01
	10	-0.14	-0.07	0.38	0.22	0.12	0.05	-3.4	-1.3	6.8	3.1	1.6	0.7	-9.92	0.18	0.69	1.09	-0.00	0.01
	15	-0.15	-0.11	0.36	0.24	0.18	0.07	-3.5	-1.7	7.0	3.1	2.1	0.9	-9.75	0.16	0.67	1.10	-0.00	0.00
	20	-0.17	-0.16	0.35	0.26	0.25	0.09	-3.6	-2.1	7.1	3.1	2.5	1.1	-9.62	0.15	0.66	1.11	-0.00	0.00
22	5	-0.15	-0.05	0.60	0.09	0.09	0.02	-4.7	-0.7	9.5	2.0	1.1	0.2	-8.28	-0.08	0.62	1.13	0.00	0.00
	10	-0.15	-0.09	0.54	0.10	0.15	0.03	-5.1	-0.9	10.0	2.1	1.3	0.3	-7.99	-0.10	0.56	1.13	0.01	0.00
	15	-0.20	-0.12	0.55	0.12	0.21	0.04	-5.5	-1.1	10.5	2.2	1.5	0.3	-8.01	-0.11	0.56	1.13	0.01	0.00
	20	-0.25	-0.15	0.44	0.13	0.28	0.05	-6.0	-1.3	11.1	2.3	1.6	0.3	-8.14	-0.11	0.54	1.14	0.01	0.00
23	5	0.04	-0.05	-0.03	0.01	0.09	0.02	-3.2	-0.7	6.7	1.4	1.2	0.2	-4.54	-0.32	0.22	1.13	0.02	0.00
	10	0.06	-0.08	-0.10	0.00	0.14	0.03	-3.6	-1.0	7.0	1.5	1.4	0.3	-4.34	-0.35	0.20	1.13	0.03	0.00
	15	0.06	-0.11	-0.19	0.01	0.19	0.04	-4.1	-1.1	7.3	1.5	1.5	0.3	-4.38	-0.36	0.20	1.13	0.03	0.00
	20	0.05	-0.15	-0.25	0.01	0.25	0.04	-4.6	-1.2	7.7	1.5	1.6	0.3	-4.45	-0.36	0.19	1.13	0.03	0.00
24	5	-0.13	-0.06	0.28	0.08	0.11	0.03	-4.9	-0.8	9.5	2.3	1.2	0.3	-10.20	0.03	0.55	1.13	0.01	0.00
	10	-0.13	-0.10	0.19	0.08	0.18	0.04	-5.6	-1.2	10.1	2.4	1.5	0.4	-9.68	-0.03	0.49	1.13	0.01	0.00
	15	-0.17	-0.15	0.02	0.09	0.27	0.05	-6.4	-1.4	10.8	2.5	1.8	0.4	-9.82	-0.03	0.47	1.14	0.01	0.00
	20	-0.23	-0.19	-0.05	0.11	0.35	0.07	-7.2	-1.6	11.3	2.6	2.0	0.5	-10.00	-0.03	0.46	1.14	0.02	0.00
25	5	-0.20	-0.04	0.39	0.16	0.08	0.03	-4.6	-0.8	7.8	2.6	1.0	0.3	-15.60	0.41	0.78	1.10	-0.01	0.00
	10	-0.29	-0.07	0.46	0.21	0.12	0.04	-5.2	-1.1	8.3	2.8	1.4	0.4	-15.87	0.43	0.77	1.11	-0.01	0.00
	15	-0.40	-0.11	0.51	0.25	0.18	0.05	-5.5	-1.4	8.7	2.8	1.7	0.5	-16.04	0.43	0.78	1.11	-0.01	0.00
	20	-0.53	-0.14	0.59	0.28	0.24	0.06	-5.7	-1.7	9.0	2.9	2.0	0.6	-16.30	0.45	0.78	1.11	-0.01	0.00
26	5	-0.25	-0.04	0.21	0.18	0.09	0.03	-3.6	-0.8	7.3	3.1	1.0	0.4	-17.94	0.51	1.08	1.07	-0.02	0.01
	10	-0.33	-0.07	0.36	0.23	0.12	0.05	-4.2	-1.2	7.3	3.3	1.6	0.7	-17.81	0.49	1.08	1.08	-0.02	0.01
	15	-0.37	-0.11	0.38	0.24	0.18	0.06	-4.2	-1.7	7.3	3.2	2.0	0.9	-18.30	0.52	1.08	1.09	-0.02	0.01
	20	-0.42	-0.15	0.41	0.26	0.25	0.09	-3.9	-2.3	7.2	3.1	2.5	1.1	-18.45	0.52	1.09	1.10	-0.02	0.01
27	5	-0.29	-0.04	0.41	0.25	0.09	0.05	-4.3	-1.0	8.0	4.3	1.4	0.7	-15.70	0.22	1.07	1.09	-0.01	0.00
	10	-0.37	-0.08	0.46	0.28	0.14	0.07	-4.2	-1.8	7.9	4.3	2.3	1.1	-15.69	0.20	1.07	1.10	-0.01	0.00
	15	-0.39	-0.14	0.53	0.27	0.21	0.11	-3.7	-2.7	7.4	4.0	3.3	1.6	-15.32	0.16	1.07	1.11	-0.01	0.00
	20	-0.35	-0.22	0.45	0.24	0.30	0.15	-3.1	-3.7	6.1	3.2	4.6	2.2	-15.64	0.18	1.07	1.12	-0.01	0.00

TABLE (A)III-3. CORN, NO TILLAGE, FALL FERTILIZATION (A,B,C,D SOILS

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.15	-0.05	0.97	0.30	0.40	0.06	-5.7	-0.8	34.0	7.5	2.1	0.6	-1.71	-0.03	0.00	1.16	0.00	0.00
	10	-0.16	-0.14	2.29	0.36	0.49	0.12	-9.0	-1.5	40.6	9.3	3.8	0.9	-1.69	-0.03	0.00	1.17	0.00	0.00
	15	-0.40	-0.25	3.80	0.56	0.64	0.18	-14.2	-2.4	48.9	11.1	6.5	1.5	-1.90	-0.00	0.01	1.17	0.00	0.00
	20	-0.78	-0.40	4.82	0.82	0.95	0.25	-17.9	-4.3	55.2	12.5	12.7	2.9	-1.95	0.00	0.01	1.17	0.00	0.00
2	5	-0.04	-0.06	3.73	0.11	0.11	0.05	-3.6	-0.9	25.7	4.6	2.5	0.6	-0.44	-0.19	0.01	1.17	0.00	-0.00
	10	-0.08	-0.11	4.55	0.18	0.17	0.08	-5.1	-1.8	28.1	5.4	4.3	0.9	-0.31	-0.20	0.01	1.17	0.01	-0.00
	15	-0.22	-0.18	5.35	0.31	0.27	0.11	-7.9	-2.5	30.8	5.9	6.6	1.3	-0.04	-0.23	0.01	1.17	0.01	-0.00
	20	-0.46	-0.26	5.79	0.48	0.43	0.14	-10.1	-3.3	31.9	6.1	9.6	1.9	-0.09	-0.22	0.01	1.17	0.01	0.00
3	5	-0.01	-0.02	0.98	0.04	0.19	0.02	-0.8	-0.4	13.9	1.4	1.4	0.2	-1.90	-0.27	0.00	1.15	0.00	0.00
	10	0.03	-0.05	1.26	0.02	0.20	0.03	-0.8	-0.7	14.3	1.5	1.7	0.3	-1.68	-0.30	0.00	1.16	0.00	0.00
	15	0.07	-0.07	1.43	0.02	0.23	0.04	-1.0	-1.0	14.3	1.6	1.9	0.4	-1.67	-0.31	0.00	1.16	0.00	0.00
	20	0.12	-0.10	1.65	0.00	0.25	0.05	-1.4	-1.2	14.2	1.7	2.2	0.4	-1.55	-0.33	0.01	1.16	0.00	0.00
4	5	-0.17	-0.02	0.57	0.21	0.27	0.03	-2.0	-0.6	18.5	3.2	1.8	0.4	-5.07	-0.06	0.03	1.14	0.00	0.00
	10	-0.14	-0.06	1.00	0.22	0.31	0.05	-2.1	-1.2	20.0	3.5	2.6	0.7	-4.70	-0.10	0.04	1.15	0.00	0.00
	15	-0.08	-0.11	1.44	0.23	0.36	0.08	-2.5	-1.9	20.5	3.9	3.6	0.9	-4.78	-0.10	0.05	1.15	0.00	0.00
	20	-0.01	-0.18	1.96	0.24	0.41	0.11	-2.7	-3.1	18.3	4.0	5.7	1.3	-4.78	-0.10	0.06	1.16	0.00	0.00
5	5	-0.01	-0.02	1.16	0.06	0.18	0.03	-1.3	-0.4	15.4	2.4	1.5	0.3	-4.15	-0.36	0.06	1.15	0.00	0.00
	10	0.02	-0.05	1.52	0.06	0.20	0.05	-1.2	-0.8	16.4	2.5	2.0	0.5	-3.89	-0.39	0.06	1.16	0.00	0.00
	15	0.07	-0.08	1.91	0.05	0.21	0.06	-1.0	-1.4	16.9	2.5	2.4	0.7	-3.74	-0.42	0.07	1.16	0.00	0.00
	20	0.12	-0.12	2.19	0.05	0.24	0.08	-1.0	-2.1	16.3	2.6	3.3	0.9	-3.93	-0.42	0.07	1.16	0.00	0.00
6	5	-0.39	-0.03	-0.66	0.37	0.48	0.05	-7.6	-1.0	36.5	8.1	2.3	0.7	-8.27	0.16	-0.01	1.15	0.00	0.00
	10	-0.23	-0.15	-0.21	0.32	0.64	0.11	-14.1	-2.7	44.8	11.3	4.8	1.3	-5.94	-0.07	-0.01	1.16	0.00	0.00
	15	-0.04	-0.35	-0.03	0.27	0.91	0.21	-21.3	-5.8	54.1	14.2	9.2	2.4	-5.74	-0.08	-0.01	1.16	0.00	0.00
	20	0.23	-0.65	0.19	0.22	1.30	0.34	-27.7	-11.7	62.4	16.4	17.4	4.4	-3.71	-0.27	-0.01	1.17	0.00	0.00
7	5	-0.33	-0.03	0.84	0.36	0.25	0.04	-4.3	-0.7	22.1	5.6	1.7	0.6	-8.23	0.04	0.06	1.15	0.00	0.00
	10	-0.39	-0.08	1.51	0.45	0.30	0.07	-5.9	-1.8	25.2	6.9	3.2	1.1	-7.54	-0.04	0.07	1.15	-0.00	0.00
	15	-0.49	-0.17	2.67	0.60	0.33	0.12	-8.3	-3.4	27.2	8.3	5.6	1.7	-7.38	-0.06	0.08	1.16	-0.00	0.00
	20	-0.64	-0.31	3.40	0.76	0.46	0.18	-8.8	-6.7	27.9	8.8	9.9	2.9	-7.24	-0.08	0.09	1.16	-0.00	0.00
8	5	-0.10	-0.02	1.11	0.16	0.12	0.02	-1.4	-0.4	12.3	2.4	1.2	0.3	-11.01	0.21	0.15	1.12	-0.01	0.00
	10	-0.10	-0.03	1.35	0.18	0.14	0.03	-1.4	-0.7	13.2	2.5	1.7	0.5	-11.04	0.21	0.16	1.13	-0.01	0.00
	15	-0.09	-0.06	1.53	0.20	0.16	0.05	-1.3	-1.1	13.9	2.6	2.1	0.6	-11.02	0.19	0.16	1.13	-0.01	0.00
	20	-0.07	-0.10	1.78	0.21	0.18	0.07	-1.0	-1.6	14.0	2.5	2.5	0.8	-11.55	0.23	0.17	1.13	-0.01	0.00
9	5	-0.36	-0.08	1.09	0.33	0.29	0.08	-11.0	-1.8	34.9	10.8	2.7	1.1	-25.92	0.75	0.35	1.14	-0.02	0.00
	10	-0.41	-0.21	1.47	0.37	0.43	0.16	-22.5	-4.7	43.2	15.9	5.5	2.3	-27.06	0.88	0.43	1.14	-0.02	0.00
	15	-0.44	-0.52	1.50	0.41	0.72	0.30	-34.4	-9.4	49.9	19.8	11.3	4.2	-28.23	0.96	0.47	1.15	-0.03	0.00
	20	-0.49	-1.03	1.08	0.43	1.32	0.52	-56.4	-10.9	71.3	27.4	13.2	4.9	-28.17	0.91	0.48	1.15	-0.03	0.00

TABLE A(III)-3. (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.25	-0.04	1.85	0.34	0.12	0.06	-5.5	-1.0	22.8	7.7	2.0	0.8	-25.87	0.92	0.50	1.12	-0.02	0.00
	10	-0.31	-0.11	2.06	0.43	0.23	0.11	-7.8	-2.7	26.8	9.6	3.2	1.7	-25.65	0.92	0.51	1.13	-0.02	0.00
	15	-0.25	-0.25	1.68	0.40	0.40	0.19	-11.1	-5.4	26.3	11.2	6.0	2.8	-25.84	0.94	0.50	1.14	-0.02	0.00
	20	-0.14	-0.53	1.29	0.37	0.66	0.33	-10.8	-10.9	22.8	11.0	12.3	5.2	-25.64	0.91	0.48	1.15	-0.02	0.00
11	5	-0.17	-0.03	1.20	0.33	0.10	0.04	-3.1	-0.6	13.9	5.3	1.3	0.6	-17.84	0.41	0.41	1.11	-0.01	0.00
	10	-0.20	-0.06	1.34	0.40	0.14	0.07	-3.6	-1.2	15.9	6.1	1.9	1.0	-17.23	0.38	0.40	1.12	-0.01	0.00
	15	-0.17	-0.12	1.55	0.44	0.19	0.11	-3.8	-2.3	17.1	6.6	2.6	1.5	-16.94	0.35	0.42	1.13	-0.02	0.00
	20	-0.11	-0.22	1.77	0.46	0.26	0.17	-4.0	-3.7	16.3	7.1	4.1	2.2	-17.38	0.39	0.44	1.13	-0.02	0.00
12	5	-0.14	-0.02	0.44	0.20	0.13	0.02	-1.8	-0.4	10.3	2.8	1.1	0.3	-9.45	0.17	0.09	1.11	0.00	0.00
	10	-0.16	-0.03	0.49	0.23	0.16	0.04	-1.7	-0.6	11.0	2.9	1.5	0.5	-9.66	0.18	0.09	1.11	0.00	0.00
	15	-0.16	-0.06	0.55	0.25	0.19	0.05	-1.5	-1.0	11.4	3.0	1.8	0.7	-9.83	0.19	0.09	1.12	0.00	0.00
	20	-0.14	-0.09	0.67	0.25	0.21	0.07	-1.4	-1.4	11.2	3.1	2.4	0.8	-9.99	0.19	0.10	1.12	0.00	0.00
13	5	-0.08	-0.02	0.87	0.20	0.07	0.03	-1.4	-0.4	7.9	2.7	1.0	0.4	-12.93	0.34	0.52	1.09	-0.02	0.01
	10	-0.10	-0.03	1.00	0.23	0.09	0.04	-1.2	-0.7	8.4	2.8	1.3	0.6	-12.85	0.33	0.52	1.09	-0.02	0.01
	15	-0.09	-0.06	1.14	0.25	0.10	0.06	-1.0	-1.0	8.8	2.9	1.6	0.8	-12.78	0.33	0.54	1.10	-0.02	0.01
	20	-0.06	-0.09	1.22	0.26	0.13	0.08	-0.7	-1.3	9.0	2.9	1.9	0.9	-12.85	0.34	0.55	1.11	-0.02	0.00
14	5	-0.06	-0.02	0.77	0.19	0.07	0.03	-1.4	-0.4	7.9	2.8	1.1	0.5	-13.51	0.35	0.52	1.09	-0.02	0.01
	10	-0.07	-0.04	0.94	0.22	0.09	0.04	-1.2	-0.7	8.4	2.9	1.4	0.7	-13.51	0.35	0.53	1.09	-0.02	0.01
	15	-0.04	-0.07	1.02	0.23	0.12	0.06	-0.9	-1.1	8.8	2.9	1.6	0.8	-13.32	0.33	0.54	1.10	-0.02	0.01
	20	-0.01	-0.10	1.16	0.24	0.14	0.09	-0.5	-1.5	9.0	3.0	1.9	1.0	-13.20	0.32	0.55	1.11	-0.02	0.00
15	5	-0.07	-0.02	0.51	0.19	0.07	0.03	-1.1	-0.4	6.1	2.6	1.0	0.5	-10.54	0.11	0.27	1.07	-0.01	0.01
	10	-0.05	-0.04	0.59	0.20	0.09	0.05	-0.8	-0.7	6.2	2.6	1.3	0.7	-10.39	0.09	0.28	1.08	-0.01	0.01
	15	-0.02	-0.06	0.63	0.20	0.11	0.06	-0.4	-1.1	6.1	2.4	1.6	0.9	-10.08	0.05	0.28	1.09	-0.01	0.01
	20	0.03	-0.10	0.63	0.19	0.14	0.09	0.1	-1.6	5.5	2.2	2.1	1.2	-9.98	0.04	0.28	1.10	-0.01	0.01
16	5	-0.07	-0.01	1.39	0.13	0.14	0.02	-1.1	-0.3	13.9	2.4	1.2	0.3	-5.45	-0.23	0.15	1.14	0.00	0.00
	10	-0.03	-0.03	1.82	0.12	0.14	0.04	-1.2	-0.6	15.0	2.5	1.5	0.4	-5.15	-0.27	0.17	1.14	-0.00	0.00
	15	-0.01	-0.06	2.04	0.13	0.16	0.05	-1.3	-0.9	15.8	2.7	1.8	0.5	-5.19	-0.27	0.18	1.15	-0.00	0.00
	20	0.01	-0.09	2.36	0.14	0.16	0.07	-1.4	-1.3	16.1	2.8	2.1	0.6	-5.54	-0.26	0.19	1.15	-0.00	0.00
17	5	-0.06	-0.01	1.20	0.10	0.13	0.02	-0.9	-0.3	12.1	1.9	1.1	0.2	-10.02	0.03	0.21	1.13	-0.00	0.00
	10	-0.04	-0.03	1.57	0.10	0.14	0.03	-0.8	-0.5	12.9	2.0	1.4	0.3	-9.46	-0.04	0.24	1.14	-0.01	0.00
	15	-0.03	-0.05	1.84	0.11	0.14	0.05	-0.8	-0.8	13.5	2.1	1.6	0.4	-9.80	-0.03	0.25	1.14	-0.01	0.00
	20	-0.02	-0.08	2.09	0.13	0.15	0.06	-0.7	-1.1	13.9	2.2	1.9	0.5	-10.11	-0.01	0.26	1.14	-0.01	0.00
18	5	-0.08	-0.01	0.98	0.13	0.08	0.02	-0.9	-0.2	8.8	1.8	1.0	0.2	-13.72	0.32	0.45	1.10	-0.02	0.00
	10	-0.07	-0.02	1.17	0.14	0.09	0.03	-0.9	-0.4	9.3	1.9	1.2	0.3	-13.61	0.32	0.47	1.11	-0.02	0.00
	15	-0.07	-0.04	1.34	0.15	0.10	0.04	-0.8	-0.5	9.6	2.0	1.4	0.4	-13.67	0.32	0.48	1.11	-0.02	0.00
	20	-0.06	-0.06	1.56	0.16	0.11	0.05	-0.6	-0.8	9.9	2.0	1.6	0.5	-13.88	0.34	0.49	1.12	-0.02	0.00

TABLE A(III)-4. (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.09	-0.02	1.58	0.17	0.04	0.02	-1.4	-0.4	8.9	2.4	1.0	0.3	-15.29	0.47	0.44	1.10	-0.02	0.00
	10	-0.09	-0.04	1.78	0.19	0.04	0.04	-1.3	-0.6	9.5	2.5	1.2	0.5	-15.85	0.52	0.47	1.10	-0.02	0.00
	15	-0.09	-0.06	1.89	0.21	0.05	0.05	-1.2	-0.8	9.9	2.6	1.4	0.6	-15.98	0.53	0.48	1.11	-0.02	0.00
	20	-0.08	-0.08	1.97	0.22	0.07	0.07	-0.9	-1.2	10.3	2.6	1.6	0.7	-16.05	0.53	0.48	1.11	-0.02	0.00
20	5	-0.06	-0.02	1.10	0.18	0.06	0.03	-1.3	-0.4	8.5	2.8	1.0	0.4	-11.10	0.22	0.33	1.10	-0.01	0.00
	10	-0.06	-0.04	1.24	0.21	0.08	0.04	-1.3	-0.7	9.2	2.9	1.3	0.6	-10.99	0.21	0.34	1.11	-0.02	0.00
	15	-0.03	-0.07	1.35	0.22	0.09	0.06	-1.1	-1.1	9.7	3.0	1.6	0.8	-10.79	0.19	0.36	1.11	-0.02	0.00
	20	-0.00	-0.10	1.47	0.23	0.11	0.08	-0.9	-1.5	9.8	3.1	2.0	0.9	-10.86	0.19	0.36	1.12	-0.02	0.00
21	5	-0.06	-0.02	0.81	0.18	0.07	0.03	-1.3	-0.4	7.2	2.7	0.9	0.4	-9.92	0.18	0.28	1.09	-0.01	0.01
	10	-0.07	-0.04	0.89	0.20	0.09	0.05	-1.1	-0.7	7.6	2.7	1.3	0.6	-9.92	0.18	0.28	1.09	-0.01	0.01
	15	-0.05	-0.07	0.94	0.21	0.11	0.06	-0.8	-1.1	7.7	2.7	1.6	0.8	-9.75	0.16	0.29	1.10	-0.01	0.00
	20	-0.02	-0.10	1.00	0.22	0.13	0.09	-0.4	-1.5	7.3	2.7	2.1	1.0	-9.62	0.15	0.29	1.11	-0.01	0.00
22	5	-0.05	-0.01	1.37	0.08	0.10	0.01	-0.6	-0.2	10.9	1.4	1.0	0.2	-8.28	-0.08	0.18	1.13	-0.00	0.00
	10	-0.03	-0.02	1.71	0.08	0.09	0.02	-0.5	-0.3	11.4	1.4	1.2	0.2	-7.99	-0.10	0.20	1.13	-0.01	0.00
	15	-0.03	-0.03	1.88	0.08	0.09	0.03	-0.4	-0.5	11.7	1.4	1.3	0.3	-8.01	-0.11	0.20	1.13	-0.01	0.00
	20	-0.01	-0.05	2.11	0.09	0.10	0.04	-0.3	-0.7	12.0	1.5	1.4	0.3	-8.14	-0.11	0.21	1.14	-0.01	0.00
23	5	0.02	-0.01	0.69	0.01	0.14	0.01	-0.2	-0.2	8.2	0.9	1.0	0.2	-4.54	-0.32	0.14	1.13	0.00	0.00
	10	0.04	-0.02	0.78	0.00	0.14	0.02	-0.1	-0.4	8.4	0.9	1.1	0.2	-4.34	-0.35	0.14	1.13	0.00	0.00
	15	0.06	-0.03	0.84	-0.00	0.15	0.03	-0.0	-0.5	8.5	0.9	1.3	0.3	-4.38	-0.36	0.15	1.13	0.00	0.00
	20	0.08	-0.05	0.91	-0.01	0.16	0.03	0.1	-0.7	8.7	0.9	1.3	0.3	-4.45	-0.36	0.15	1.13	0.00	0.00
24	5	-0.04	-0.01	1.22	0.07	0.13	0.02	-0.7	-0.3	11.3	1.6	1.1	0.2	-10.20	0.03	0.18	1.13	-0.00	0.00
	10	-0.02	-0.03	1.47	0.06	0.13	0.03	-0.7	-0.5	11.9	1.6	1.4	0.3	-9.68	-0.03	0.20	1.13	-0.00	0.00
	15	0.00	-0.05	1.65	0.06	0.14	0.04	-0.6	-0.7	12.3	1.7	1.5	0.4	-9.82	-0.03	0.20	1.14	-0.00	0.00
	20	0.03	-0.07	1.80	0.06	0.16	0.05	-0.5	-1.0	12.6	1.7	1.7	0.4	-10.00	-0.03	0.21	1.14	-0.00	0.00
25	5	-0.06	-0.01	0.89	0.14	0.09	0.02	-1.0	-0.3	9.0	2.0	1.0	0.3	-15.60	0.41	0.19	1.10	-0.00	0.00
	10	-0.08	-0.02	0.98	0.17	0.11	0.03	-0.8	-0.5	9.5	2.1	1.2	0.4	-15.87	0.43	0.19	1.11	-0.00	0.00
	15	-0.08	-0.04	1.06	0.19	0.12	0.04	-0.6	-0.7	9.8	2.1	1.5	0.5	-16.04	0.43	0.19	1.11	-0.00	0.00
	20	-0.08	-0.06	1.15	0.21	0.14	0.05	-0.3	-1.1	10.0	2.1	1.7	0.6	-16.30	0.45	0.20	1.11	-0.00	0.00
26	5	-0.13	-0.02	0.43	0.16	0.09	0.03	-1.5	-0.4	7.9	2.8	1.0	0.4	-17.94	0.51	0.15	1.07	-0.00	0.01
	10	-0.16	-0.03	0.48	0.20	0.11	0.04	-1.4	-0.7	8.2	2.8	1.4	0.6	-17.81	0.49	0.16	1.08	-0.00	0.01
	15	-0.15	-0.06	0.50	0.21	0.13	0.06	-1.0	-1.1	8.1	2.7	1.7	0.8	-18.30	0.52	0.16	1.09	-0.00	0.01
	20	-0.14	-0.09	0.48	0.21	0.16	0.08	-0.5	-1.7	7.7	2.6	2.1	1.1	-18.45	0.52	0.16	1.10	-0.00	0.01
27	5	-9.16	-0.02	0.40	0.22	0.10	0.04	-1.9	-0.5	8.8	4.0	1.2	0.7	-15.70	0.22	0.19	1.09	0.00	0.00
	10	-0.17	-0.05	0.39	0.24	0.14	0.07	-1.4	-1.2	8.8	3.9	1.9	1.1	-15.69	0.20	0.19	1.10	0.00	0.00
	15	-0.14	-0.10	0.31	0.23	0.20	0.10	-0.7	-2.2	7.3	3.6	2.9	1.6	-15.32	0.16	0.18	1.11	0.00	0.00
	20	-0.07	-0.17	0.25	0.20	0.27	0.15	0.5	-3.4	4.8	2.9	4.3	2.2	-15.64	0.18	0.18	1.12	0.00	0.00

TABLE A(III)-4. FALL PLOW CORN (A SOILS ONLY)

REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′
1	5	0.69	0.92	-0.63	47.86	10	5	1.45	0.72	-1.38	54.00	19	5	1.13	6.61	-1.10	61.52
	10	0.62	0.94	-0.51	36.11		10	1.41	0.70	-1.14	39.60		10	1.13	6.45	-1.04	54.46
	15	0.57	0.86	-0.43	27.45		15	1.33	0.60	-1.01	30.73		15	1.10	6.34	-0.97	49.50
	20	0.51	0.90	-0.38	19.86		20	1.28	0.58	-0.90	23.35		20	1.08	6.17	-0.95	45.53
2	5	1.09	2.84	-1.05	51.16	11	5	1.31	2.93	-1.26	60.02	20	5	1.16	7.09	-1.13	61.63
	10	1.02	2.92	-0.93	40.87		10	1.25	2.94	-1.04	47.42		10	1.17	6.93	-1.06	53.08
	15	0.96	2.94	-0.82	33.33		15	1.23	2.75	-0.91	39.46		15	1.16	6.80	-0.98	47.29
	20	0.89	3.08	-0.75	27.67		20	1.20	2.57	-0.82	33.10		20	1.12	6.68	-0.88	42.44
3	5	1.50	4.76	-1.49	63.32	12	5	1.70	2.62	-1.67	64.49	21	5	1.37	7.86	-1.35	61.98
	10	1.54	4.51	-1.53	57.81		10	1.76	2.39	-1.68	56.17		10	1.41	7.61	-1.32	53.80
	15	1.54	4.43	-1.54	54.60		15	1.79	2.22	-1.64	50.47		15	1.40	7.41	-1.26	48.20
	20	1.53	4.30	-1.53	51.95		20	1.79	1.98	-1.58	45.84		20	1.38	7.26	-1.22	43.88
4	5	1.60	0.92	-1.57	58.45	13	5	1.23	9.18	-1.19	62.53	22	5	1.31	4.10	-1.30	66.25
	10	1.63	0.66	-1.53	49.01		10	1.22	9.15	-1.08	53.91		10	1.33	3.90	-1.31	60.76
	15	1.60	0.58	-1.44	42.32		15	1.20	9.02	-0.95	48.06		15	1.32	3.84	-1.32	57.36
	20	1.56	0.47	-1.44	37.24		20	1.18	8.84	-0.85	43.42		20	1.33	3.69	-1.32	54.57
5	5	1.54	2.65	-1.52	59.92	14	5	1.06	9.78	-1.02	60.24	23	5	1.16	12.06	-1.15	65.54
	10	1.57	2.51	-1.49	52.17		10	1.07	9.57	-0.90	51.46		10	1.18	11.90	-1.15	61.19
	15	1.56	2.36	-1.49	46.98		15	1.06	9.39	-0.80	45.71		15	1.20	11.81	-1.19	58.38
	20	1.56	2.24	-1.48	42.68		20	1.01	9.20	-0.71	41.13		20	1.20	11.72	-1.19	55.99
6	5	1.12	-1.05	-1.03	45.17	15	5	1.78	7.27	-1.76	62.09	24	5	1.36	4.83	-1.35	64.32
	10	1.06	-1.14	-0.81	31.12		10	1.82	6.92	-1.75	54.38		10	1.37	4.61	-1.33	58.09
	15	0.98	-1.06	-0.65	22.50		15	1.84	6.63	-1.76	49.77		15	1.37	4.50	-1.34	54.16
	20	0.91	-0.97	-0.58	16.09		20	1.84	6.42	-1.77	46.26		20	1.36	4.44	-1.34	50.96
7	5	1.60	-1.46	-1.53	53.32	16	5	1.12	4.58	-1.09	61.28	25	5	1.52	4.33	-1.50	66.85
	10	1.64	-1.74	-1.41	40.18		10	1.10	4.42	-1.02	53.95		10	1.53	4.26	-1.48	59.39
	15	1.61	-1.91	-1.22	31.41		15	1.08	4.37	-0.97	48.55		15	1.55	4.09	-1.50	54.34
	20	1.57	-1.93	-1.08	24.52		20	1.07	4.23	-0.98	44.64		20	1.55	3.94	-1.49	50.39
8	5	1.62	2.31	-1.58	61.99	17	5	1.34	3.70	-1.32	63.41	26	5	2.23	1.69	-2.21	66.01
	10	1.68	2.04	-1.59	54.05		10	1.36	3.51	-1.30	56.45		10	2.30	1.32	-2.25	57.82
	15	1.70	1.85	-1.56	48.65		15	1.34	3.40	-1.28	51.53		15	2.35	0.95	-2.30	53.27
	20	1.70	1.62	-1.56	44.58		20	1.34	3.31	-1.27	47.25		20	2.36	0.82	-2.32	49.71
9	5	1.49	-1.61	-1.37	45.60	18	5	0.95	7.82	-0.94	64.26	27	5	2.58	-0.48	-2.56	62.80
	10	1.39	-1.65	-1.03	30.01		10	0.94	7.70	-0.90	57.76		10	2.66	-0.93	-2.61	54.08
	15	1.33	-1.64	-0.95	21.64		15	0.92	7.60	-0.86	53.05		15	2.74	-1.43	-2.63	48.67
	20	1.26	-1.56	-0.90	15.20		20	0.90	7.45	-0.86	49.12		20	2.79	-1.82	-2.66	44.56

TABLE A(III)-5. FALL PLOW CORN, SPRING FERTILIZATION (A SOIL ONLY)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
1	5	-0.09	-0.14	2.17	0.30	0.24	0.07	-14.3	-0.2	43.3	9.5	0.6	0.1	0.19	-0.38	0.31	1.17	0.06	-0.00
	10	-0.74	-0.17	2.84	0.58	0.40	0.09	-17.9	-0.2	54.5	12.1	0.7	0.2	0.24	-0.40	0.27	1.17	0.06	-0.00
	15	-1.43	-0.17	4.03	0.98	0.56	0.10	-22.7	-0.3	69.3	15.3	1.0	0.2	0.20	-0.40	0.24	1.18	0.07	-0.00
	20	-2.35	-0.17	6.52	1.55	0.62	0.11	-30.3	-0.5	92.6	20.5	1.6	0.4	0.15	-0.39	0.23	1.18	0.07	-0.00
2	5	0.01	-0.13	0.43	0.06	0.29	0.07	-11.8	-0.2	35.9	6.6	0.8	0.1	0.39	-0.40	0.03	1.18	0.08	-0.00
	10	-0.36	-0.16	0.78	0.21	0.44	0.08	-14.4	-0.3	44.1	8.1	1.0	0.2	0.42	-0.40	0.02	1.18	0.08	-0.00
	15	-0.83	-0.16	1.49	0.41	0.57	0.09	-17.2	-0.4	53.3	9.8	1.2	0.2	0.49	-0.41	-0.01	1.18	0.08	-0.00
	20	-1.32	-0.16	2.72	0.67	0.64	0.10	-20.3	-0.5	62.7	11.5	1.5	0.3	0.47	-0.40	-0.01	1.18	0.07	-0.00
3	5	0.10	-0.09	0.42	0.01	0.13	0.03	-7.1	-0.3	17.6	2.7	0.5	0.1	0.23	-0.68	0.07	1.17	0.07	-0.00
	10	0.10	-0.13	0.28	0.02	0.22	0.04	-8.5	-0.4	19.5	3.0	0.7	0.1	0.35	-0.71	0.05	1.17	0.07	-0.00
	15	0.07	-0.17	0.22	0.04	0.30	0.05	-9.9	-0.5	20.9	3.2	0.7	0.1	0.39	-0.73	0.04	1.17	0.07	-0.00
	20	0.02	-0.20	0.18	0.05	0.38	0.06	-11.1	-0.5	22.1	3.4	0.7	0.1	0.45	-0.74	0.02	1.17	0.08	-0.00
4	5	0.08	-0.13	1.02	0.12	0.16	0.05	-10.5	-0.5	22.8	5.0	0.8	0.2	-0.60	-0.75	0.29	1.17	0.07	-0.00
	10	-0.04	-0.18	0.95	0.20	0.29	0.06	-13.8	-0.8	27.4	6.0	1.1	0.2	-0.39	-0.77	0.26	1.17	0.07	-0.00
	15	-0.25	-0.22	1.07	0.31	0.39	0.07	-17.6	-1.0	32.0	6.9	1.4	0.3	-0.31	-0.79	0.23	1.17	0.07	-0.00
	20	-0.60	-0.26	1.44	0.45	0.49	0.08	-20.8	-1.2	36.1	7.8	1.8	0.4	-0.22	-0.81	0.20	1.17	0.08	-0.00
5	5	0.20	-0.13	0.34	0.02	0.16	0.05	-9.6	-0.4	18.6	4.1	0.6	0.1	-0.77	-1.00	0.13	1.17	0.07	-0.00
	10	0.18	-0.18	0.21	0.06	0.27	0.06	-11.9	-0.6	21.6	4.7	0.8	0.2	-0.67	-1.02	0.11	1.17	0.07	-0.00
	15	0.11	-0.23	0.15	0.10	0.37	0.07	-14.2	-0.7	24.1	5.3	1.0	0.2	-0.57	-1.06	0.09	1.17	0.08	-0.00
	20	-0.04	-0.28	0.23	0.16	0.46	0.09	-16.8	-0.9	26.7	5.8	1.1	0.3	-0.62	-1.07	0.09	1.17	0.08	-0.00
6	5	-0.30	-0.13	4.63	0.48	-0.16	0.04	-21.8	-0.8	42.2	10.7	1.3	0.3	-1.11	-0.89	0.66	1.17	0.04	-0.00
	10	-1.04	-0.17	5.82	0.91	-0.09	0.04	-35.2	-1.4	60.7	15.1	2.0	0.5	0.24	-1.02	0.58	1.17	0.05	-0.00
	15	-2.55	-0.17	7.61	1.56	-0.01	0.03	-51.3	-2.1	82.4	20.4	3.0	0.7	0.46	-1.04	0.55	1.18	0.05	-0.00
	20	-4.87	-0.12	10.71	2.44	-0.03	0.00	-70.8	-3.5	109.9	27.1	5.0	1.2	0.80	-1.07	0.53	1.18	0.06	-0.00
7	5	-0.20	-0.10	2.63	0.42	-0.06	0.03	-12.4	-0.7	24.8	7.5	1.1	0.3	-3.22	-0.71	0.64	1.16	0.05	-0.00
	10	-0.66	-0.13	3.01	0.75	0.02	0.03	-18.5	-1.2	33.1	9.7	1.8	0.5	-2.83	-0.75	0.60	1.17	0.05	-0.00
	15	-1.60	-0.13	3.90	1.25	0.08	0.02	-25.3	-1.8	42.1	12.2	2.5	0.7	-2.71	-0.77	0.55	1.17	0.05	-0.00
	20	-2.90	-0.11	5.47	1.82	0.12	0.01	-33.8	-2.6	52.8	15.2	3.7	1.1	-2.71	-0.78	0.53	1.17	0.06	-0.00
8	5	0.06	-0.10	0.42	0.12	0.14	0.04	-8.7	-0.3	14.7	4.0	0.5	0.1	-4.15	-0.82	0.30	1.15	0.06	-0.00
	10	-0.02	-0.15	0.35	0.18	0.23	0.05	-10.6	-0.5	17.0	4.5	0.6	0.2	-4.10	-0.82	0.29	1.15	0.06	-0.00
	15	-0.16	-0.18	0.33	0.25	0.31	0.05	-12.2	-0.6	19.0	5.0	0.7	0.2	-4.04	-0.85	0.28	1.16	0.07	-0.00
	20	-0.35	-0.21	0.42	0.33	0.38	0.06	-13.7	-0.7	20.8	5.4	0.8	0.2	-4.10	-0.87	0.26	1.16	0.07	-0.00
9	5	-0.67	-0.15	1.15	0.84	0.26	0.02	-29.0	-1.5	38.3	14.4	1.7	0.6	-21.97	0.21	0.92	1.15	0.02	0.00
	10	-1.80	-0.18	1.38	1.38	0.41	0.02	-47.4	-2.6	58.3	21.2	2.8	1.1	-23.96	0.43	0.96	1.15	0.02	0.00
	15	-3.77	-0.17	2.78	2.20	0.51	0.02	-64.6	-4.9	77.1	27.7	5.3	2.0	-25.43	0.54	0.98	1.16	0.02	0.00
	20	-6.39	-0.21	5.45	3.22	0.60	0.03	-81.2	-8.0	95.5	33.8	8.7	3.2	-26.12	0.57	1.01	1.16	0.02	0.00

TABLE A(III)-5 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.30	-0.12	0.86	0.69	0.19	0.02	-18.5	-0.8	24.7	11.0	0.8	0.4	-20.57	0.24	0.85	1.14	0.02	0.00
	10	-0.91	-0.15	0.93	1.08	0.29	0.02	-27.3	-1.3	34.2	14.8	1.3	0.6	-20.99	0.32	0.86	1.15	0.02	0.00
	15	-1.80	-0.16	1.35	1.49	0.39	0.02	-37.0	-1.9	44.4	18.8	1.9	0.9	-21.53	0.40	0.87	1.15	0.02	0.00
	20	-2.99	-0.20	2.31	1.99	0.49	0.04	-49.3	-3.0	57.6	24.0	2.9	1.4	-21.92	0.44	0.89	1.16	0.02	0.00
11	5	-0.02	-0.12	0.76	0.48	0.13	0.03	-11.5	-0.3	16.0	7.9	0.4	0.2	-12.71	-0.37	0.65	1.14	0.03	0.00
	10	-0.20	-0.16	0.77	0.64	0.20	0.04	-16.1	-0.5	20.7	9.9	0.5	0.3	-12.65	-0.33	0.65	1.14	0.03	0.00
	15	-0.53	-0.19	0.86	0.86	0.29	0.04	-20.4	-0.6	25.3	11.9	0.6	0.3	-12.55	-0.34	0.65	1.15	0.04	0.00
	20	-1.05	-0.21	1.24	1.14	0.35	0.05	-25.3	-0.8	30.4	14.1	0.7	0.4	-12.69	-0.33	0.65	1.15	0.04	0.00
12	5	0.01	-0.07	1.22	0.17	0.01	0.03	-6.0	-0.3	12.5	4.1	0.4	0.1	-4.72	-0.52	0.56	1.14	0.04	-0.00
	10	-0.04	-0.10	1.16	0.22	0.07	0.04	-7.4	-0.4	14.4	4.6	0.6	0.2	-4.85	-0.51	0.56	1.14	0.04	-0.00
	15	-0.14	-0.13	1.17	0.29	0.13	0.05	-8.9	-0.6	16.3	5.1	0.7	0.2	-4.88	-0.52	0.55	1.15	0.04	-0.00
	20	-0.29	-0.15	1.25	0.37	0.19	0.06	-10.6	-0.7	18.1	5.7	0.8	0.3	-4.87	-0.53	0.54	1.15	0.05	-0.00
13	5	0.04	-0.08	0.28	0.21	0.11	0.03	-6.3	-0.2	10.7	4.6	0.2	0.1	-8.75	-0.27	0.52	1.12	0.03	-0.00
	10	-0.02	-0.10	0.25	0.27	0.16	0.04	-8.1	-0.3	12.7	5.3	0.3	0.1	-8.80	-0.25	0.53	1.12	0.03	0.00
	15	-0.12	-0.12	0.26	0.34	0.21	0.05	-9.7	-0.3	14.5	5.9	0.2	0.1	-8.79	-0.25	0.53	1.13	0.03	0.00
	20	-0.23	-0.15	0.33	0.41	0.25	0.05	-11.3	-0.3	16.2	6.6	0.2	0.1	-8.77	-0.25	0.52	1.13	0.03	0.00
14	5	0.06	-0.08	0.17	0.20	0.10	0.03	-6.9	-0.2	10.9	4.9	0.2	0.1	-8.84	-0.34	0.45	1.12	0.03	-0.00
	10	0.01	-0.11	0.14	0.27	0.16	0.04	-8.9	-0.2	13.0	5.7	0.2	0.1	-8.89	-0.33	0.45	1.13	0.03	-0.00
	15	-0.08	-0.14	0.15	0.33	0.22	0.05	-10.6	-0.2	14.9	6.4	0.2	0.1	-8.81	-0.34	0.44	1.13	0.03	0.00
	20	-0.19	-0.16	0.20	0.40	0.26	0.06	-12.2	-0.2	16.6	7.1	0.2	0.1	-8.73	-0.34	0.43	1.13	0.03	0.00
15	5	0.04	-0.06	0.38	0.25	0.06	0.02	-4.6	-0.3	8.3	4.2	0.3	0.2	-6.18	-0.54	0.43	1.11	0.04	-0.00
	10	0.04	-0.09	0.34	0.29	0.11	0.03	-5.8	-0.4	9.6	4.8	0.4	0.2	-6.12	-0.54	0.43	1.12	0.05	-0.00
	15	0.02	-0.11	0.31	0.34	0.15	0.04	-6.7	-0.5	10.6	5.2	0.5	0.3	-5.94	-0.57	0.42	1.13	0.05	-0.00
	20	-0.02	-0.14	0.32	0.38	0.19	0.05	-7.5	-0.6	11.5	5.5	0.6	0.3	-5.84	-0.58	0.41	1.13	0.05	0.00
16	5	0.12	-0.10	0.93	0.09	0.10	0.04	-8.5	-0.3	16.9	4.0	0.4	0.1	-3.29	-0.75	0.37	1.15	0.05	-0.00
	10	0.08	-0.16	0.82	0.12	0.19	0.06	-11.1	-0.3	19.6	4.6	0.4	0.1	-3.17	-0.78	0.35	1.16	0.05	-0.00
	15	-0.02	-0.20	0.88	0.16	0.28	0.07	-13.6	-0.3	22.1	5.2	0.4	0.1	-3.19	-0.79	0.34	1.16	0.05	-0.00
	20	-0.19	-0.25	1.00	0.22	0.36	0.08	-15.7	-0.3	24.1	5.6	0.5	0.1	-3.24	-0.82	0.33	1.16	0.05	-0.00
17	5	0.13	-0.11	0.33	0.06	0.13	0.04	-8.1	-0.3	13.7	3.6	0.3	0.1	-4.19	-0.97	0.24	1.15	0.06	-0.00
	10	0.14	-0.17	0.24	0.07	0.21	0.05	-9.3	-0.3	15.6	4.0	0.4	0.1	-3.90	-1.01	0.22	1.15	0.06	-0.00
	15	0.03	-0.21	0.10	0.12	0.30	0.07	-11.4	-0.4	17.3	4.4	0.4	0.1	-3.95	-1.04	0.20	1.16	0.06	-0.00
	20	-0.12	-0.25	0.15	0.47	0.38	0.08	-13.2	-0.4	19.0	4.8	0.5	0.1	-4.01	-1.06	0.20	1.16	0.07	-0.00
18	5	0.03	-0.08	0.19	0.11	0.11	0.03	-6.3	-0.1	10.5	3.4	0.1	0.1	-9.90	-0.27	0.41	1.13	0.04	-0.00
	10	-0.04	-0.11	0.16	0.15	0.16	0.04	-7.6	-0.2	11.7	3.8	0.2	0.1	-9.87	-0.27	0.39	1.13	0.04	-0.00
	15	-0.16	-0.13	0.12	0.19	0.22	0.04	-8.9	-0.2	13.0	4.1	0.2	0.1	-9.90	-0.27	0.39	1.14	0.04	-0.00
	20	-0.32	-0.14	0.11	0.25	0.27	0.05	-10.3	-0.2	14.2	4.5	0.2	0.1	-9.96	-0.27	0.38	1.14	0.04	-0.00

TABLE A(III)-5. (CONT)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	0.06	-0.10	-0.06	0.14	0.15	0.03	-7.4	-0.2	11.0	4.2	0.2	0.1	-9.12	-0.44	0.35	1.13	0.04	-0.00
	10	-0.01	-0.13	-0.15	0.18	0.22	0.05	-8.9	-0.3	12.6	4.7	0.2	0.1	-9.23	-0.44	0.34	1.13	0.05	-0.00
	15	-0.13	-0.16	-0.19	0.24	0.29	0.06	-10.5	-0.3	14.1	5.2	0.2	0.1	-9.28	-0.45	0.34	1.14	0.05	-0.00
	20	-0.26	-0.19	-0.13	0.29	0.34	0.07	-11.9	-0.3	15.4	5.6	0.2	0.1	-9.24	-0.47	0.33	1.14	0.05	-0.00
20	5	0.08	-0.08	0.42	0.18	0.07	0.03	-6.4	-0.2	11.2	4.6	0.2	0.1	-6.76	-0.46	0.39	1.13	0.04	-0.00
	10	0.06	-0.12	0.36	0.22	0.14	0.04	-8.4	-0.3	13.4	5.3	0.3	0.1	-6.77	-0.44	0.39	1.13	0.04	-0.00
	15	-0.02	-0.15	0.33	0.29	0.20	0.05	-10.2	-0.3	15.3	6.0	0.3	0.1	-6.67	-0.46	0.38	1.14	0.04	-0.00
	20	-0.15	-0.17	0.38	0.36	0.26	0.06	-11.9	-0.3	17.2	6.6	0.3	0.1	-6.65	-0.47	0.37	1.14	0.04	-0.00
21	5	0.05	-0.07	0.38	0.20	0.06	0.03	-5.4	-0.2	9.9	4.4	0.3	0.1	-6.27	-0.38	0.40	1.12	0.04	-0.00
	10	0.02	-0.10	0.32	0.25	0.12	0.04	-6.8	-0.3	11.6	5.1	0.3	0.1	-6.32	-0.37	0.40	1.13	0.04	-0.00
	15	-0.05	-0.12	0.29	0.31	0.18	0.05	-8.1	-0.4	13.1	5.6	0.4	0.2	-6.22	-0.38	0.39	1.13	0.04	-0.00
	20	-0.15	-0.14	0.32	0.37	0.23	0.05	-9.3	-0.5	14.5	6.2	0.4	0.2	-6.15	-0.38	0.39	1.14	0.04	-0.00
22	5	0.09	-0.09	0.39	0.06	0.12	0.03	-6.5	-0.2	12.4	2.6	0.3	0.1	-5.37	-0.63	0.33	1.15	0.05	-0.00
	10	0.07	-0.13	0.33	0.07	0.18	0.04	-7.4	-0.2	13.6	2.9	0.3	0.1	-5.27	-0.64	0.31	1.15	0.06	-0.00
	15	-0.01	-0.15	0.29	0.11	0.24	0.04	-8.3	-0.3	14.6	3.1	0.4	0.1	-5.32	-0.64	0.30	1.15	0.06	-0.00
	20	-0.13	-0.17	0.26	0.14	0.31	0.05	-9.2	-0.3	15.5	3.2	0.4	0.1	-5.39	-0.65	0.29	1.15	0.06	-0.00
23	5	0.13	-0.08	-0.10	0.00	0.12	0.02	-6.7	-0.2	11.0	2.2	0.2	0.0	-2.77	-0.75	0.12	1.15	0.04	-0.00
	10	0.13	-0.12	-0.19	0.00	0.18	0.03	-7.8	-0.2	12.0	2.4	0.2	0.0	-2.68	-0.77	0.11	1.15	0.05	-0.00
	15	0.13	-0.15	-0.22	0.01	0.24	0.04	-8.5	-0.2	12.7	2.6	0.2	0.0	-2.66	-0.79	0.11	1.15	0.05	-0.00
	20	0.10	-0.18	-0.22	0.01	0.28	0.05	-9.2	-0.2	13.3	2.7	0.2	0.0	-2.67	-0.80	0.11	1.15	0.05	-0.00
24	5	0.11	-0.10	0.29	0.04	0.11	0.03	-7.1	-0.2	12.8	3.1	0.3	0.1	-4.61	-0.90	0.24	1.15	0.06	-0.00
	10	0.10	-0.15	0.22	0.04	0.17	0.05	-8.7	-0.3	14.4	3.4	0.4	0.1	-4.33	-0.94	0.22	1.15	0.06	-0.00
	15	0.04	-0.19	0.11	0.07	0.25	0.06	-10.2	-0.4	15.8	3.7	0.4	0.1	-4.33	-0.97	0.21	1.15	0.06	-0.00
	20	-0.08	-0.22	0.11	0.11	0.32	0.07	-11.6	-0.4	16.9	3.9	0.4	0.1	-4.38	-0.99	0.20	1.16	0.06	-0.00
25	5	0.12	-0.12	-0.14	0.14	0.20	0.03	-7.4	-0.2	10.9	3.5	0.3	0.1	-7.92	-0.71	0.31	1.13	0.05	-0.00
	10	0.04	-0.15	-0.18	0.18	0.25	0.04	-8.6	-0.3	12.3	4.0	0.3	0.1	-8.02	-0.71	0.31	1.14	0.05	-0.00
	15	-0.05	-0.18	-0.16	0.22	0.31	0.05	-9.6	-0.4	13.5	4.3	0.4	0.1	-8.07	-0.72	0.31	1.14	0.05	-0.00
	20	-0.17	-0.20	-0.06	0.27	0.35	0.06	-10.7	-0.4	14.7	4.6	0.4	0.2	-8.17	-0.72	0.32	1.14	0.05	-0.00
26	5	-0.11	-0.09	0.08	0.27	0.16	0.02	-6.6	-0.4	9.5	4.1	0.4	0.2	-12.23	-0.30	0.61	1.11	0.04	0.00
	10	-0.21	-0.11	0.10	0.33	0.21	0.03	-7.5	-0.6	10.8	4.6	0.6	0.3	-12.18	-0.30	0.60	1.11	0.04	0.00
	15	-0.28	-0.14	0.11	0.38	0.25	0.04	-8.3	-0.8	11.6	4.9	0.8	0.4	-12.31	-0.30	0.59	1.12	0.04	0.00
	20	-0.38	-0.16	0.19	0.45	0.29	0.04	-9.0	-0.9	12.4	5.1	0.9	0.4	-12.44	-0.30	0.60	1.12	0.04	0.00
27	5	-0.21	-0.08	0.19	0.51	0.14	0.01	-7.1	-0.6	10.6	5.4	0.7	0.4	-10.06	-0.54	0.58	1.12	0.04	0.00
	10	-0.31	-0.11	0.31	0.63	0.19	0.01	-8.3	-1.0	12.0	6.0	1.2	0.6	-9.95	-0.56	0.57	1.12	0.04	0.00
	15	-0.40	-0.14	0.41	0.75	0.24	0.02	-9.4	-1.3	13.1	6.3	1.5	0.9	-9.49	-0.61	0.56	1.13	0.05	0.00
	20	-0.50	-0.17	0.51	0.86	0.28	0.03	-10.0	-1.7	13.7	6.5	2.0	1.1	-9.53	-0.62	0.56	1.14	0.05	0.00

TABLE A(III)-6. FALL PLOW CORN, FALL FERTILIZATION (A SOIL ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.01	-0.07	4.30	0.28	-0.21	0.06	-7.7	-0.1	39.5	9.0	0.6	0.1	0.19	-0.38	0.05	1.17	-0.00	-0.00
	10	-0.28	-0.11	6.22	0.54	-0.29	0.09	-13.2	-0.2	50.8	11.8	0.8	0.2	0.24	-0.40	0.05	1.17	-0.00	-0.00
	15	-0.79	-0.14	8.48	0.93	-0.37	0.10	-20.8	-0.4	66.1	15.2	1.2	0.2	0.20	-0.40	0.05	1.18	-0.00	-0.00
	20	-1.71	-0.16	10.94	1.50	-0.38	0.11	-29.7	-0.6	89.0	20.5	1.9	0.4	0.15	-0.39	0.05	1.18	0.00	-0.00
2	5	0.04	-0.07	4.78	0.06	-0.20	0.06	-6.2	-0.2	32.2	6.2	0.8	0.1	0.39	-0.40	0.04	1.18	0.00	-0.00
	10	-0.11	-0.10	5.83	0.19	-0.22	0.08	-10.2	-0.4	39.7	7.8	1.2	0.2	0.42	-0.40	0.04	1.18	0.00	-0.00
	15	-0.39	-0.12	6.92	0.38	-0.23	0.09	-15.1	-0.5	48.8	9.6	1.5	0.2	0.49	-0.41	0.04	1.18	0.00	-0.00
	20	-0.82	-0.14	7.97	0.63	-0.22	0.09	-20.0	-0.6	58.5	11.5	1.9	0.3	0.47	-0.40	0.04	1.18	0.00	-0.00
3	5	0.03	-0.03	2.46	0.02	-0.09	0.02	-2.0	-0.1	17.3	2.1	0.5	0.1	0.23	-0.68	0.04	1.17	0.00	-0.00
	10	0.04	-0.04	2.92	0.02	-0.12	0.03	-2.9	-0.1	18.3	2.3	0.6	0.1	0.35	-0.71	0.04	1.17	0.00	-0.00
	15	0.05	-0.06	3.29	0.03	-0.13	0.04	-3.8	-0.2	18.8	2.6	0.7	0.1	0.39	-0.73	0.04	1.17	0.00	-0.00
	20	0.04	-0.07	3.64	0.04	-0.14	0.04	-4.8	-0.3	19.3	2.8	0.8	0.1	0.45	-0.74	0.04	1.17	0.00	-0.00
4	5	0.04	-0.05	3.23	0.12	-0.17	0.04	-3.3	-0.1	22.0	4.2	0.8	0.1	-0.60	-0.75	0.07	1.17	-0.00	-0.00
	10	0.01	-0.06	4.25	0.18	-0.23	0.05	-5.0	-0.3	25.1	5.1	1.1	0.2	-0.39	-0.77	0.07	1.17	-0.00	-0.00
	15	-0.04	-0.09	5.27	0.27	-0.29	0.06	-7.3	-0.5	27.9	6.0	1.4	0.3	-0.31	-0.79	0.08	1.17	-0.00	-0.00
	20	-0.15	-0.11	6.31	0.38	-0.35	0.07	-10.2	-0.8	30.0	7.0	2.0	0.4	-0.22	-0.81	0.08	1.17	-0.00	-0.00
5	5	0.09	-0.04	2.88	0.04	-0.12	0.03	-2.5	-0.1	18.7	3.2	0.6	0.1	-0.77	-1.00	0.11	1.17	-0.00	-0.00
	10	0.10	-0.06	3.47	0.06	-0.15	0.05	-3.4	-0.2	20.8	3.7	0.8	0.1	-0.67	-1.02	0.11	1.17	-0.00	-0.00
	15	0.09	-0.07	4.08	0.09	-0.19	0.06	-4.7	-0.3	22.2	4.3	1.0	0.2	-0.57	-1.06	0.12	1.17	-0.00	-0.00
	20	0.06	-0.09	4.63	0.13	-0.21	0.07	-6.5	-0.5	23.3	4.9	1.2	0.2	-0.62	-1.07	0.12	1.17	-0.00	-0.00
6	5	-0.19	-0.06	5.32	0.46	-0.43	0.03	-9.7	-0.3	40.2	9.4	1.2	0.3	-1.11	-0.89	0.05	1.17	-0.00	-0.00
	10	-0.50	-0.09	8.29	0.82	-0.64	0.03	-19.8	-0.8	53.6	13.9	1.9	0.5	0.24	-1.02	0.06	1.17	-0.00	-0.00
	15	-1.33	-0.11	11.33	1.41	-0.83	0.03	-34.0	-1.5	72.6	19.2	3.0	0.7	0.46	-1.04	0.07	1.18	-0.00	-0.00
	20	-2.89	-0.09	14.58	2.27	-0.98	0.00	-53.3	-3.0	98.3	25.8	5.1	1.2	0.80	-1.07	0.07	1.18	-0.00	-0.00
7	5	-0.13	-0.05	5.03	0.41	-0.38	0.03	-5.7	-0.3	24.3	6.6	1.0	0.3	-3.22	-0.71	0.13	1.16	-0.01	-0.00
	10	-0.36	-0.06	7.07	0.70	-0.53	0.03	-9.5	-0.7	29.9	8.9	1.7	0.5	-2.83	-0.75	0.14	1.17	-0.01	-0.00
	15	-0.85	-0.07	9.57	1.14	-0.71	0.02	-15.2	-1.1	36.4	11.5	2.5	0.7	-2.71	-0.77	0.15	1.17	-0.01	-0.00
	20	-1.66	-0.08	11.65	1.69	-0.84	0.01	-22.3	-2.1	45.5	14.4	3.9	1.0	-2.71	-0.78	0.16	1.17	-0.01	-0.00
8	5	0.02	-0.03	2.77	0.12	-0.16	0.02	-2.4	-0.1	15.0	3.1	0.5	0.1	-4.15	-0.82	0.17	1.15	-0.01	-0.00
	10	-0.00	-0.04	3.32	0.17	-0.20	0.03	-3.2	-0.1	16.7	3.6	0.7	0.1	-4.10	-0.82	0.18	1.15	-0.01	-0.00
	15	-0.04	-0.06	3.81	0.22	-0.23	0.04	-4.1	-0.2	18.1	4.0	0.9	0.2	-4.04	-0.85	0.18	1.16	-0.01	-0.00
	20	-0.09	-0.07	4.35	0.28	-0.26	0.05	-5.1	-0.3	19.0	4.5	1.0	0.2	-4.10	-0.87	0.19	1.16	-0.01	-0.00
9	5	-0.45	-0.06	5.20	0.80	-0.37	0.01	-14.1	-0.8	38.5	12.5	1.6	0.6	-21.97	0.21	0.45	1.15	-0.03	0.00
	10	-1.05	-0.09	6.66	1.24	-0.43	0.01	-31.0	-1.9	51.9	19.8	2.8	1.1	-23.96	0.43	0.52	1.15	-0.04	0.00
	15	-2.52	-0.11	8.31	2.02	-0.45	0.02	-50.5	-4.1	67.7	26.6	5.4	1.9	-25.43	0.54	0.55	1.16	-0.04	0.00
	20	-4.98	-0.15	10.36	3.09	-0.37	0.03	-68.7	-7.0	84.8	32.8	8.9	3.1	-26.12	0.57	0.57	1.16	-0.04	0.00

TABLE A(III)-6. (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.27	-0.04	3.90	0.68	-0.25	0.01	-7.8	-0.3	26.5	9.5	0.9	0.3	-20.57	0.24	0.53	1.14	-0.03	0.00
	10	-0.53	-0.06	5.12	1.01	-0.32	0.01	-14.2	-0.7	33.2	13.3	1.3	0.6	-20.99	0.32	0.55	1.15	-0.03	0.00
	15	-0.97	-0.09	5.59	1.34	-0.30	0.02	-23.8	-1.4	39.5	17.7	1.9	0.8	-21.53	0.40	0.54	1.15	-0.03	0.00
	20	-1.79	-0.14	6.18	1.81	-0.26	0.04	-36.4	-2.5	50.4	23.0	3.2	1.3	-21.92	0.44	0.54	1.16	-0.03	0.00
11	5	-0.08	-0.04	2.50	0.49	-0.15	0.02	-4.7	-0.1	17.1	6.9	0.5	0.2	-12.71	-0.37	0.48	1.14	-0.03	0.00
	10	-0.15	-0.06	3.02	0.62	-0.17	0.02	-7.1	-0.2	20.8	8.8	0.6	0.2	-12.65	-0.33	0.48	1.14	-0.03	0.00
	15	-0.28	-0.08	3.66	0.80	-0.21	0.03	-10.2	-0.3	23.8	10.8	0.7	0.3	-12.55	-0.34	0.49	1.15	-0.03	0.00
	20	-0.53	-0.10	4.32	1.05	-0.24	0.04	-14.5	-0.5	26.9	13.1	0.8	0.4	-12.69	-0.33	0.49	1.15	-0.03	0.00
12	5	-0.01	-0.03	2.02	0.17	-0.13	0.03	-2.7	-0.1	12.5	3.6	0.5	0.1	-4.72	-0.52	0.19	1.14	-0.01	-0.00
	10	-0.04	-0.05	2.34	0.22	-0.15	0.03	-3.4	-0.2	14.0	4.1	0.6	0.2	-4.85	-0.51	0.19	1.14	-0.01	-0.00
	15	-0.08	-0.06	2.69	0.27	-0.17	0.04	-4.1	-0.2	15.1	4.6	0.8	0.2	-4.88	-0.52	0.19	1.15	-0.01	-0.00
	20	-0.14	-0.07	3.08	0.34	-0.19	0.05	-5.1	-0.3	16.2	5.1	0.9	0.2	-4.87	-0.53	0.20	1.15	-0.01	-0.00
13	5	-0.00	-0.03	1.27	0.21	-0.02	0.02	-2.7	-0.1	11.0	4.1	0.2	0.1	-8.75	-0.27	0.46	1.12	-0.02	-0.00
	10	-0.04	-0.04	1.50	0.26	-0.03	0.03	-3.3	-0.1	12.5	4.7	0.3	0.1	-8.80	-0.25	0.46	1.12	-0.02	0.00
	15	-0.07	-0.05	1.74	0.33	-0.04	0.04	-4.0	-0.1	13.7	5.3	0.3	0.1	-8.79	-0.25	0.47	1.13	-0.02	0.00
	20	-0.12	-0.06	1.94	0.39	-0.05	0.04	-4.9	-0.1	14.8	5.9	0.3	0.1	-8.77	-0.25	0.47	1.13	-0.02	0.00
14	5	0.01	-0.03	1.11	0.21	-0.01	0.02	-2.8	-0.1	11.2	4.3	0.2	0.1	-8.84	-0.34	0.45	1.12	-0.02	-0.00
	10	-0.02	-0.04	1.39	0.26	-0.02	0.03	-3.6	-0.1	12.9	5.1	0.3	0.1	-8.89	-0.33	0.45	1.13	-0.02	-0.00
	15	-0.05	-0.05	1.61	0.32	-0.03	0.04	-4.4	-0.1	14.1	5.7	0.3	0.1	-8.81	-0.34	0.45	1.13	-0.02	0.00
	20	-0.10	-0.06	1.84	0.38	-0.04	0.05	-5.3	-0.1	15.3	6.4	0.3	0.1	-8.73	-0.34	0.46	1.13	-0.02	0.00
15	5	0.01	-0.03	0.96	0.25	-0.02	0.02	-2.3	-0.1	8.5	3.9	0.3	0.1	-6.18	-0.54	0.31	1.11	-0.01	-0.00
	10	0.00	-0.04	1.19	0.29	-0.04	0.03	-2.8	-0.1	9.4	4.4	0.5	0.2	-6.12	-0.54	0.32	1.12	-0.01	-0.00
	15	-0.01	-0.05	1.39	0.33	-0.05	0.03	-3.4	-0.2	10.0	4.8	0.6	0.2	-5.94	-0.57	0.32	1.13	-0.01	-0.00
	20	-0.03	-0.06	1.56	0.38	-0.05	0.04	-4.0	-0.3	10.5	5.1	0.6	0.3	-5.84	-0.58	0.32	1.13	-0.01	0.00
16	5	0.04	-0.03	2.72	0.10	-0.09	0.03	-2.1	-0.0	17.2	3.2	0.4	0.1	-3.29	-0.75	0.22	1.15	-0.01	-0.00
	10	0.04	-0.05	3.15	0.11	-0.11	0.04	-2.9	-0.1	19.1	3.7	0.4	0.1	-3.17	-0.78	0.22	1.16	-0.01	-0.00
	15	0.01	-0.06	3.52	0.15	-0.13	0.05	-4.0	-0.1	20.7	4.2	0.5	0.1	-3.19	-0.79	0.23	1.16	-0.01	-0.00
	20	-0.02	-0.08	3.92	0.19	-0.14	0.06	-5.4	-0.2	21.7	4.6	0.6	0.1	-3.24	-0.82	0.23	1.16	-0.01	-0.00
17	5	0.04	-0.03	2.42	0.07	-0.08	0.03	-1.7	-0.0	14.9	2.6	0.4	0.1	-4.19	-0.97	0.23	1.15	-0.01	-0.00
	10	0.04	-0.04	2.83	0.08	-0.10	0.04	-2.2	-0.1	16.4	2.9	0.5	0.1	-3.90	-1.01	0.23	1.15	-0.01	-0.00
	15	0.03	-0.06	3.22	0.10	-0.12	0.05	-2.9	-0.1	17.5	3.3	0.5	0.1	-3.95	-1.04	0.24	1.16	-0.01	-0.00
	20	0.01	-0.07	3.60	0.13	-0.14	0.05	-3.9	-0.2	18.6	3.7	0.6	0.1	-4.01	-1.06	0.24	1.16	-0.01	-0.00
18	5	-0.01	-0.02	1.42	0.12	-0.02	0.02	-1.6	-0.0	12.0	2.6	0.2	0.0	-9.90	-0.27	0.42	1.13	-0.01	-0.00
	10	-0.03	-0.03	1.70	0.14	-0.03	0.03	-2.0	-0.0	13.1	2.9	0.2	0.0	-9.87	-0.27	0.42	1.13	-0.02	-0.00
	15	-0.05	-0.04	1.93	0.17	-0.04	0.03	-2.5	-0.1	14.0	3.2	0.3	0.0	-9.90	-0.27	0.42	1.14	-0.02	-0.00
	20	-0.08	-0.04	2.17	0.20	-0.05	0.04	-3.1	-0.1	14.8	3.5	0.3	0.1	-9.96	-0.27	0.43	1.14	-0.02	-0.00

TABLE A(III)-6 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	0.01	-0.03	1.97	0.15	-0.07	0.03	-2.5	-0.0	11.7	3.5	0.2	0.1	-9.12	-0.44	0.37	1.13	-0.01	-0.00
	10	-0.01	-0.05	2.17	0.18	-0.07	0.04	-3.1	-0.1	13.0	3.9	0.3	0.1	-9.23	-0.44	0.38	1.13	-0.02	-0.00
	15	-0.04	-0.06	2.33	0.21	-0.08	0.05	-3.7	-0.1	14.1	4.3	0.3	0.1	-9.28	-0.45	0.38	1.14	-0.02	-0.00
	20	-0.07	-0.07	2.47	0.25	-0.08	0.05	-4.5	-0.1	14.9	4.7	0.3	0.1	-9.24	-0.47	0.38	1.14	-0.02	-0.00
20	5	0.03	-0.04	1.79	0.19	-0.09	0.03	-2.7	-0.1	11.4	4.0	0.3	0.1	-6.76	-0.46	0.33	1.13	-0.02	-0.00
	10	0.02	-0.05	2.03	0.23	-0.10	0.04	-3.5	-0.1	13.0	4.7	0.3	0.1	-6.77	-0.44	0.33	1.13	-0.02	-0.00
	15	-0.01	-0.06	2.24	0.28	-0.11	0.04	-4.4	-0.1	14.3	5.3	0.4	0.1	-6.67	-0.46	0.33	1.14	-0.02	-0.00
	20	-0.06	-0.07	2.44	0.34	-0.12	0.05	-5.5	-0.1	15.6	6.0	0.4	0.1	-6.65	-0.47	0.33	1.14	-0.02	-0.00
21	5	0.02	-0.03	1.51	0.21	-0.07	0.02	-2.6	-0.1	9.8	4.0	0.3	0.1	-6.27	-0.38	0.29	1.12	-0.02	-0.00
	10	0.00	-0.05	1.70	0.25	-0.08	0.03	-3.3	-0.1	11.1	4.6	0.4	0.1	-6.32	-0.37	0.30	1.13	-0.02	-0.00
	15	-0.03	-0.06	1.85	0.29	-0.09	0.04	-4.0	-0.2	12.1	5.2	0.4	0.2	-6.22	-0.38	0.30	1.13	-0.02	-0.00
	20	-0.07	-0.07	2.02	0.35	-0.09	0.05	-4.8	-0.2	13.0	5.7	0.5	0.2	-6.15	-0.38	0.29	1.14	-0.02	-0.00
22	5	0.03	-0.02	2.83	0.06	-0.17	0.02	-1.1	-0.0	13.3	1.8	0.3	0.0	-5.37	-0.63	0.25	1.15	-0.02	-0.00
	10	0.03	-0.03	3.18	0.07	-0.19	0.02	-1.4	-0.0	14.2	2.0	0.4	0.0	-5.27	-0.64	0.26	1.15	-0.02	-0.00
	15	0.02	-0.04	3.47	0.09	-0.21	0.03	-1.7	-0.1	14.8	2.2	0.5	0.1	-5.32	-0.64	0.26	1.15	-0.02	-0.00
	20	0.01	-0.04	3.79	0.11	-0.23	0.03	-2.3	-0.1	15.2	2.3	0.5	0.1	-5.39	-0.65	0.27	1.15	-0.02	-0.00
23	5	0.05	-0.02	1.40	0.01	-0.00	0.01	-1.0	-0.0	11.5	1.5	0.2	0.0	-2.77	-0.75	0.17	1.15	0.00	-0.00
	10	0.05	-0.02	1.53	0.01	-0.00	0.02	-1.3	-0.0	12.1	1.6	0.2	0.0	-2.68	-0.77	0.17	1.15	0.00	-0.00
	15	0.05	-0.03	1.64	0.01	-0.01	0.02	-1.6	-0.0	12.5	1.7	0.3	0.0	-2.66	-0.79	0.17	1.15	0.00	-0.00
	20	0.05	-0.04	1.76	0.01	-0.01	0.03	-2.0	-0.1	12.8	1.8	0.3	0.0	-2.67	-0.80	0.17	1.15	0.00	-0.00
24	5	0.03	-0.03	2.45	0.05	-0.09	0.02	-1.5	-0.0	14.2	2.2	0.4	0.1	-4.61	-0.90	0.21	1.15	-0.01	-0.00
	10	0.03	-0.04	2.76	0.05	-0.11	0.03	-2.0	-0.1	15.4	2.4	0.4	0.1	-4.33	-0.94	0.22	1.15	-0.01	-0.00
	15	0.03	-0.05	3.04	0.06	-0.12	0.04	-2.6	-0.1	16.1	2.7	0.5	0.1	-4.33	-0.97	0.22	1.15	-0.01	-0.00
	20	0.01	-0.06	3.33	0.08	-0.13	0.05	-3.4	-0.1	16.7	2.9	0.6	0.1	-4.38	-0.99	0.22	1.16	-0.01	-0.00
25	5	0.04	-0.03	2.08	0.14	-0.12	0.02	-1.7	-0.0	11.4	2.8	0.3	0.1	-7.92	-0.71	0.27	1.13	-0.01	-0.00
	10	0.03	-0.04	2.32	0.17	-0.13	0.03	-2.1	-0.1	12.5	3.1	0.4	0.1	-8.02	-0.71	0.27	1.14	-0.01	-0.00
	15	0.01	-0.05	2.55	0.20	-0.14	0.03	-2.6	-0.1	13.4	3.4	0.5	0.1	-8.07	-0.72	0.27	1.14	-0.02	-0.00
	20	-0.01	-0.06	2.78	0.23	-0.16	0.04	-3.3	-0.2	14.0	3.8	0.6	0.1	-8.17	-0.72	0.27	1.14	-0.02	-0.00
26	5	-0.05	-0.03	1.77	0.25	-0.12	0.01	-2.4	-0.1	9.4	3.5	0.5	0.2	-12.23	-0.30	0.31	1.11	-0.02	0.00
	10	-0.08	-0.04	2.03	0.31	-0.14	0.02	-2.9	-0.2	10.3	4.0	0.7	0.3	-12.18	-0.30	0.32	1.11	-0.02	0.00
	15	-0.10	-0.05	2.24	0.35	-0.15	0.03	-3.5	-0.3	10.7	4.3	0.9	0.3	-12.31	-0.30	0.32	1.12	-0.02	0.00
	20	-0.14	-0.06	2.42	0.40	-0.16	0.04	-4.1	-0.5	11.0	4.6	1.1	0.4	-12.44	-0.30	0.32	1.12	-0.02	0.00
27	5	-0.08	-0.03	1.37	0.49	-0.06	-0.00	-2.9	-0.2	10.4	4.9	0.8	0.4	-10.06	-0.54	0.31	1.12	-0.01	0.00
	10	-0.12	-0.04	1.77	0.61	-0.09	0.00	-3.8	-0.5	11.0	5.5	1.2	0.6	-9.95	-0.56	0.31	1.12	-0.01	0.00
	15	-0.17	-0.07	2.13	0.72	-0.10	0.01	-4.7	-0.9	11.1	5.9	1.6	0.8	-9.49	-0.61	0.29	1.13	-0.01	0.00
	20	-0.22	-0.09	2.49	0.82	-0.12	0.02	-5.6	-1.4	10.8	6.2	2.2	1.1	-9.53	-0.62	0.29	1.14	-0.01	0.00

TABLE A(III)-7. FALL PLOW CORN (B SOILS ONLY)

REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′
1	5	0.69	5.67	-0.63	43.11	10	5	1.45	5.33	-1.38	49.39	19	5	1.13	15.47	-1.10	52.65
	10	0.62	5.62	-0.51	31.44		10	1.41	5.20	-1.14	35.10		10	1.13	15.30	-1.04	45.62
	15	0.57	5.38	-0.43	22.98		15	1.33	4.89	-1.01	26.45		15	1.10	15.12	-0.97	40.72
	20	0.51	5.26	-0.38	15.57		20	1.28	4.64	-0.90	19.30		20	1.08	14.88	-0.95	36.82
2	5	1.09	8.60	-1.05	45.40	11	5	1.31	9.73	-1.26	53.22	20	5	1.16	16.08	-1.13	52.64
	10	1.02	8.63	-0.93	35.16		10	1.25	9.61	-1.04	40.75		10	1.17	15.88	-1.06	44.14
	15	0.96	8.58	-0.82	27.69		15	1.23	9.28	-0.91	32.93		15	1.16	15.68	-0.98	38.41
	20	0.89	8.64	-0.75	22.12		20	1.20	8.96	-0.82	26.71		20	1.12	15.49	-0.88	33.63
3	5	1.50	11.83	-1.49	56.25	12	5	1.70	9.15	-1.67	57.96	21	5	1.37	16.77	-1.35	53.07
	10	1.54	11.54	-1.53	50.78		10	1.76	8.86	-1.68	49.70		10	1.41	16.48	-1.32	44.93
	15	1.54	11.43	-1.54	47.61		15	1.79	8.64	-1.64	44.05		15	1.40	16.20	-1.26	39.40
	20	1.53	11.24	-1.53	45.01		20	1.79	8.34	-1.58	39.49		20	1.38	15.98	-1.22	35.16
4	5	1.60	6.36	-1.57	53.01	13	5	1.23	18.87	-1.19	52.85	22	5	1.31	11.82	-1.30	58.53
	10	1.63	6.03	-1.53	43.64		10	1.22	18.80	-1.08	44.26		10	1.33	11.61	-1.31	53.05
	15	1.60	5.86	-1.44	37.03		15	1.20	18.62	-0.95	38.46		15	1.32	11.51	-1.32	49.68
	20	1.56	5.67	-1.44	32.04		20	1.18	18.38	-0.85	33.88		20	1.33	11.31	-1.32	46.95
5	5	1.54	8.71	-1.52	53.88	14	5	1.06	19.66	-1.02	50.36	23	5	1.16	22.53	-1.15	55.06
	10	1.57	8.54	-1.49	46.17		10	1.07	19.42	-0.90	41.62		10	1.18	22.35	-1.15	50.74
	15	1.56	8.32	-1.49	41.06		15	1.06	19.17	-0.80	35.93		15	1.20	22.22	-1.19	47.96
	20	1.56	8.13	-1.48	36.85		20	1.01	18.92	-0.71	31.41		20	1.20	22.09	-1.19	45.62
6	5	1.12	1.98	-1.03	42.14	15	5	1.78	15.21	-1.76	54.15	24	5	1.36	12.60	-1.35	56.54
	10	1.06	1.80	-0.81	28.19		10	1.82	14.84	-1.75	46.46		10	1.37	12.37	-1.33	50.33
	15	0.98	1.79	-0.65	19.73		15	1.84	14.50	-1.76	41.91		15	1.37	12.21	-1.34	46.45
	20	0.91	1.78	-0.58	13.43		20	1.84	14.22	-1.77	38.46		20	1.36	12.08	-1.34	43.33
7	5	1.60	1.89	-1.53	49.97	16	5	1.12	11.95	-1.09	53.91	25	5	1.52	12.39	-1.50	58.78
	10	1.64	1.55	-1.41	36.88		10	1.10	11.76	-1.02	46.60		10	1.53	12.27	-1.48	51.38
	15	1.61	1.28	-1.22	28.23		15	1.08	11.64	-0.97	41.28		15	1.55	12.03	-1.50	46.40
	20	1.57	1.15	-1.07	21.42		20	1.07	11.44	-0.98	37.43		20	1.55	11.80	-1.49	42.53
8	5	1.62	8.53	-1.58	55.76	17	5	1.34	10.93	-1.32	56.18	26	5	2.23	7.18	-2.21	60.52
	10	1.68	8.22	-1.59	47.86		10	1.36	10.71	-1.30	49.24		10	2.30	6.76	-2.25	52.38
	15	1.70	7.97	-1.56	42.52		15	1.34	10.53	-1.28	44.40		15	2.35	6.33	-2.30	47.89
	20	1.70	7.67	-1.56	38.53		20	1.34	10.37	-1.27	40.19		20	2.36	6.12	-2.32	44.42
9	5	1.49	1.04	-1.37	42.94	18	5	0.95	17.77	-0.94	54.31	27	5	2.58	3.60	-2.56	58.72
	10	1.39	0.85	-1.03	27.52		10	0.94	17.63	-0.90	47.84		10	2.66	3.03	-2.61	50.11
	15	1.33	0.71	-0.95	19.30		15	0.92	17.46	-0.86	43.20		15	2.74	2.42	-2.63	44.81
	20	1.26	0.64	-0.87	13.26		20	0.90	17.21	-0.86	39.36		20	2.79	1.91	-2.66	40.83

TABLE A(III)-8. FALL PLOW CORN, SPRING FERTILIZATION (B SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.34	-0.09	2.78	0.47	0.16	0.04	-15.7	-0.2	47.5	10.5	0.7	0.2	-0.05	-0.24	0.34	1.17	0.04	-0.00
	10	-1.28	-0.10	4.20	0.92	0.26	0.05	-20.2	-0.3	61.4	13.6	0.9	0.2	-0.05	-0.24	0.33	1.17	0.04	-0.00
	15	-2.18	-0.11	6.17	1.46	0.36	0.06	-26.4	-0.5	80.5	17.8	1.4	0.3	-0.08	-0.24	0.32	1.18	0.04	-0.00
	20	-3.34	-0.10	9.45	2.19	0.42	0.07	-36.6	-0.8	112.1	24.8	2.5	0.6	-0.13	-0.23	0.32	1.18	0.04	-0.00
2	5	-0.13	-0.10	1.05	0.16	0.21	0.05	-13.2	-0.3	40.0	7.4	1.1	0.2	0.05	-0.28	0.13	1.18	0.05	-0.00
	10	-0.67	-0.12	1.71	0.37	0.33	0.06	-16.4	-0.4	50.4	9.3	1.4	0.3	0.06	-0.28	0.12	1.18	0.05	-0.00
	15	-1.23	-0.12	2.81	0.64	0.44	0.07	-20.2	-0.6	62.5	11.5	1.9	0.4	0.08	-0.27	0.11	1.18	0.05	-0.00
	20	-1.82	-0.13	4.41	0.95	0.51	0.08	-24.3	-0.9	75.5	13.9	2.6	0.5	0.05	-0.27	0.11	1.18	0.05	-0.00
3	5	0.05	-0.08	0.76	0.05	0.10	0.02	-8.0	-0.4	19.6	3.0	0.7	0.1	-0.10	-0.51	0.13	1.17	0.05	-0.00
	10	0.00	-0.11	0.69	0.07	0.18	0.03	-9.9	-0.6	22.0	3.4	0.9	0.1	-0.03	-0.53	0.12	1.17	0.05	-0.00
	15	-0.07	-0.15	0.73	0.10	0.25	0.04	-11.5	-0.7	23.6	3.6	1.0	0.1	-0.00	-0.54	0.11	1.17	0.05	-0.00
	20	-0.18	-0.18	0.81	0.13	0.32	0.05	-12.9	-0.7	25.1	3.8	1.0	0.2	0.03	-0.55	0.10	1.17	0.05	-0.00
4	5	0.06	-0.11	1.20	0.17	0.13	0.04	-11.6	-0.7	24.8	5.5	1.0	0.2	-0.34	-0.61	0.24	1.17	0.06	-0.00
	10	-0.18	-0.15	1.23	0.30	0.25	0.05	-15.5	-1.1	30.3	6.6	1.5	0.3	-0.24	-0.62	0.22	1.17	0.06	-0.00
	15	-0.55	-0.19	1.56	0.46	0.34	0.06	-20.0	-1.3	35.7	7.7	1.9	0.4	-0.20	-0.64	0.20	1.17	0.06	-0.00
	20	-1.09	-0.24	2.18	0.66	0.44	0.07	-23.6	-1.7	40.6	8.7	2.6	0.6	-0.16	-0.65	0.19	1.17	0.06	-0.00
5	5	0.15	-0.11	0.60	0.07	0.12	0.04	-10.7	-0.5	20.4	4.6	0.8	0.2	-0.98	-0.78	0.16	1.17	0.06	-0.00
	10	0.05	-0.15	0.56	0.14	0.22	0.05	-13.5	-0.8	24.0	5.3	1.1	0.2	-0.93	-0.79	0.15	1.17	0.06	-0.00
	15	-0.11	-0.20	0.63	0.21	0.31	0.06	-16.2	-1.0	27.1	5.9	1.3	0.3	-0.87	-0.81	0.14	1.17	0.06	-0.00
	20	-0.35	-0.24	0.87	0.29	0.39	0.07	-19.1	-1.2	30.2	6.5	1.6	0.4	-0.90	-0.83	0.13	1.17	0.06	-0.00
6	5	-0.33	-0.12	5.28	0.60	-0.15	0.03	-23.7	-0.9	44.9	11.4	1.5	0.4	-0.05	-0.79	0.55	1.18	0.04	-0.00
	10	-1.56	-0.13	6.39	1.23	-0.06	0.02	-38.8	-1.7	65.8	16.4	2.5	0.6	0.48	-0.84	0.51	1.18	0.05	-0.00
	15	-3.69	-0.11	8.96	2.09	-0.01	0.01	-57.9	-2.8	91.4	22.6	4.0	1.0	0.55	-0.84	0.49	1.18	0.05	-0.00
	20	-6.86	-0.06	13.14	3.26	-0.02	-0.02	-81.6	-5.0	124.6	30.6	7.1	1.8	0.64	-0.84	0.48	1.18	0.05	-0.00
7	5	-0.16	-0.10	3.39	0.52	-0.09	0.03	-13.6	-0.8	26.2	7.9	1.2	0.3	-1.74	-0.71	0.52	1.17	0.05	-0.00
	10	-0.79	-0.12	3.70	0.93	0.00	0.02	-20.2	-1.5	35.4	10.4	2.2	0.6	-1.55	-0.74	0.50	1.17	0.05	-0.00
	15	-1.94	-0.13	4.80	1.52	0.07	0.01	-27.9	-2.3	45.5	13.2	3.3	0.9	-1.47	-0.75	0.46	1.17	0.05	-0.00
	20	-3.50	-0.13	6.69	2.19	0.13	0.01	-37.4	-3.6	57.5	16.5	5.1	1.5	-1.46	-0.76	0.45	1.17	0.05	-0.00
8	5	0.06	-0.09	0.50	0.15	0.11	0.03	-9.8	-0.4	16.2	4.4	0.6	0.2	-2.94	-0.71	0.22	1.16	0.05	-0.00
	10	-0.05	-0.13	0.45	0.23	0.20	0.04	-11.9	-0.7	19.0	5.0	0.8	0.2	-2.90	-0.72	0.21	1.16	0.06	-0.00
	15	-0.23	-0.17	0.50	0.32	0.28	0.05	-13.8	-0.8	21.4	5.6	1.0	0.3	-2.85	-0.74	0.20	1.16	0.06	-0.00
	20	-0.47	-0.20	0.66	0.41	0.34	0.06	-15.6	-1.1	23.5	6.1	1.2	0.4	-2.85	-0.76	0.19	1.16	0.06	-0.00
9	5	-0.77	-0.14	1.43	1.18	0.22	-0.00	-30.7	-1.8	40.4	15.1	2.0	0.7	-17.86	-0.13	0.74	1.16	0.03	0.00
	10	-2.45	-0.14	2.29	2.01	0.32	-0.02	-50.9	-3.2	62.5	22.6	3.5	1.3	-18.74	-0.03	0.76	1.16	0.03	0.00
	15	-5.38	-0.10	4.82	3.26	0.38	-0.04	-69.3	-6.3	82.9	29.5	6.9	2.6	-19.59	0.02	0.77	1.17	0.03	0.00
	20	-9.48	-0.11	9.06	4.90	0.43	-0.04	-83.7	-9.4	99.0	34.6	10.5	3.9	-20.27	0.04	0.80	1.17	0.03	0.00

TABLE A(III)-8 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.37	-0.10	1.13	0.87	0.15	0.01	-20.2	-0.9	26.8	11.9	1.0	0.5	-17.28	-0.01	0.73	1.15	0.03	0.00
	10	-1.15	-0.13	1.34	1.38	0.24	0.01	-30.5	-1.7	38.0	16.3	1.7	0.8	-17.65	0.05	0.74	1.16	0.03	0.00
	15	-2.42	-0.15	2.08	2.00	0.33	0.01	-42.0	-2.7	50.3	21.1	2.7	1.2	-18.03	0.10	0.75	1.16	0.03	0.00
	20	-4.10	-0.20	3.51	2.75	0.44	0.03	-56.6	-4.8	66.2	27.2	4.8	2.2	-18.48	0.14	0.77	1.17	0.03	0.00
11	5	-0.09	-0.09	0.81	0.59	0.10	0.02	-13.0	-0.5	17.9	8.7	0.5	0.3	-11.09	-0.35	0.57	1.15	0.03	-0.00
	10	-0.34	-0.13	0.86	0.80	0.17	0.03	-18.7	-0.7	23.9	11.3	0.7	0.4	-11.09	-0.32	0.57	1.15	0.03	0.00
	15	-0.80	-0.16	1.06	1.08	0.24	0.04	-24.4	-0.9	29.9	13.9	0.9	0.5	-11.04	-0.32	0.57	1.16	0.03	0.00
	20	-1.48	-0.19	1.64	1.44	0.31	0.05	-31.1	-1.2	36.9	16.8	1.1	0.6	-11.06	-0.33	0.57	1.16	0.03	0.00
12	5	0.01	-0.06	1.41	0.21	0.01	0.03	-6.8	-0.3	13.7	4.5	0.6	0.2	-3.95	-0.45	0.50	1.15	0.04	-0.00
	10	-0.06	-0.09	1.35	0.28	0.07	0.04	-8.4	-0.6	16.0	5.1	0.8	0.2	-4.03	-0.45	0.50	1.15	0.04	-0.00
	15	-0.21	-0.12	1.39	0.36	0.13	0.04	-10.3	-0.8	18.2	5.8	1.0	0.3	-4.04	-0.46	0.49	1.15	0.04	-0.00
	20	-0.41	-0.14	1.54	0.47	0.18	0.05	-12.3	-0.9	20.5	6.4	1.2	0.4	-4.03	-0.47	0.48	1.16	0.04	-0.00
13	5	0.00	-0.06	0.35	0.27	0.08	0.02	-7.5	-0.3	12.5	5.3	0.3	0.1	-7.90	-0.22	0.49	1.13	0.02	0.00
	10	-0.09	-0.08	0.35	0.35	0.13	0.03	-10.0	-0.4	15.3	6.3	0.4	0.2	-7.95	-0.21	0.49	1.14	0.02	0.00
	15	-0.23	-0.10	0.42	0.44	0.17	0.04	-12.2	-0.4	17.9	7.2	0.4	0.2	-7.95	-0.21	0.49	1.14	0.02	0.00
	20	-0.41	-0.13	0.56	0.54	0.22	0.05	-14.4	-0.4	20.4	8.1	0.4	0.2	-7.94	-0.21	0.49	1.14	0.02	0.00
14	5	0.02	-0.06	0.28	0.27	0.07	0.02	-8.4	-0.3	12.9	5.7	0.3	0.1	-8.02	-0.27	0.42	1.13	0.02	-0.00
	10	-0.08	-0.09	0.28	0.36	0.12	0.03	-11.1	-0.4	16.0	6.9	0.4	0.2	-8.04	-0.26	0.42	1.14	0.02	0.00
	15	-0.23	-0.12	0.35	0.45	0.17	0.04	-13.6	-0.4	18.7	7.9	0.3	0.2	-8.01	-0.26	0.42	1.14	0.02	0.00
	20	-0.41	-0.14	0.50	0.56	0.22	0.05	-16.0	-0.4	21.4	8.9	0.3	0.2	-7.96	-0.26	0.41	1.15	0.02	0.00
15	5	0.04	-0.06	0.43	0.32	0.06	0.02	-5.3	-0.4	9.3	4.7	0.5	0.2	-5.57	-0.45	0.40	1.13	0.04	-0.00
	10	0.01	-0.08	0.40	0.38	0.10	0.03	-6.8	-0.6	11.1	5.4	0.7	0.3	-5.53	-0.46	0.40	1.13	0.04	-0.00
	15	-0.03	-0.11	0.39	0.44	0.14	0.04	-7.9	-0.7	12.3	5.9	0.8	0.4	-5.41	-0.47	0.39	1.14	0.04	0.00
	20	-0.10	-0.13	0.42	0.51	0.19	0.05	-8.9	-0.9	13.4	6.3	1.0	0.5	-5.35	-0.49	0.39	1.14	0.04	0.00
16	5	0.08	-0.08	1.03	0.13	0.08	0.03	-9.8	-0.3	19.1	4.6	0.5	0.1	-3.36	-0.54	0.35	1.16	0.04	-0.00
	10	-0.03	-0.12	1.01	0.18	0.15	0.04	-13.0	-0.4	22.5	5.3	0.5	0.1	-3.31	-0.55	0.34	1.16	0.04	-0.00
	15	-0.19	-0.16	1.18	0.24	0.23	0.05	-16.1	-0.5	25.6	6.0	0.6	0.1	-3.34	-0.56	0.34	1.16	0.04	-0.00
	20	-0.41	-0.20	1.41	0.32	0.30	0.06	-18.7	-0.5	28.2	6.5	0.7	0.2	-3.37	-0.58	0.33	1.16	0.04	-0.00
17	5	0.10	-0.09	0.55	0.10	0.09	0.03	-9.2	-0.3	15.3	4.0	0.4	0.1	-3.67	-0.74	0.24	1.16	0.04	-0.00
	10	0.04	-0.14	0.53	0.14	0.16	0.04	-11.3	-0.4	17.6	4.5	0.6	0.1	-3.52	-0.77	0.22	1.16	0.05	-0.00
	15	-0.11	-0.18	0.48	0.20	0.24	0.05	-13.2	-0.5	19.8	5.0	0.6	0.2	-3.55	-0.79	0.22	1.16	0.05	-0.00
	20	-0.30	-0.21	0.63	0.26	0.31	0.06	-15.4	-0.6	21.9	5.5	0.7	0.2	-3.57	-0.81	0.21	1.16	0.05	-0.00
18	5	-0.02	-0.06	0.38	0.16	0.08	0.02	-7.5	-0.2	12.2	4.0	0.2	0.1	-9.04	-0.21	0.40	1.14	0.02	-0.00
	10	-0.14	-0.08	0.40	0.22	0.12	0.03	-9.3	-0.3	14.0	4.5	0.3	0.1	-9.03	-0.20	0.39	1.14	0.03	-0.00
	15	-0.32	-0.10	0.41	0.29	0.16	0.03	-11.0	-0.3	15.8	5.0	0.3	0.1	-9.06	-0.20	0.39	1.15	0.03	-0.00
	20	-0.53	-0.11	0.50	0.36	0.21	0.04	-12.8	-0.4	17.5	5.4	0.3	0.1	-9.09	-0.21	0.38	1.15	0.03	0.00

TABLE A(III)-8 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	0.01	-0.07	0.07	0.20	0.11	0.03	-8.6	-0.3	12.8	4.8	0.3	0.1	-7.94	-0.35	0.31	1.14	0.03	-0.00
	10	-0.10	-0.10	0.05	0.26	0.16	0.04	-10.7	-0.4	15.0	5.5	0.3	0.1	-8.01	-0.35	0.31	1.14	0.03	-0.00
	15	-0.28	-0.13	0.07	0.33	0.22	0.05	-12.7	-0.4	17.0	6.2	0.3	0.1	-8.05	-0.36	0.31	1.15	0.03	-0.00
	20	-0.45	-0.15	0.21	0.40	0.26	0.05	-14.6	-0.4	18.8	6.8	0.4	0.2	-8.05	-0.37	0.31	1.15	0.03	-0.00
20	5	0.04	-0.06	0.58	0.24	0.05	0.02	-7.7	-0.3	13.0	5.3	0.4	0.1	-6.16	-0.35	0.38	1.14	0.03	-0.00
	10	-0.03	-0.09	0.55	0.31	0.11	0.03	-10.2	-0.4	15.9	6.3	0.4	0.2	-6.18	-0.34	0.38	1.14	0.03	-0.00
	15	-0.17	-0.12	0.58	0.40	0.16	0.04	-12.6	-0.5	18.5	7.2	0.5	0.2	-6.14	-0.35	0.37	1.15	0.03	-0.00
	20	-0.37	-0.14	0.73	0.50	0.21	0.05	-15.1	-0.5	21.3	8.1	0.5	0.2	-6.13	-0.35	0.37	1.15	0.03	-0.00
21	5	0.03	-0.06	0.51	0.27	0.05	0.02	-6.5	-0.3	11.4	5.1	0.4	0.2	-5.70	-0.30	0.38	1.13	0.03	-0.00
	10	-0.04	-0.08	0.46	0.33	0.10	0.03	-8.3	-0.5	13.6	5.9	0.5	0.2	-5.73	-0.30	0.38	1.14	0.03	-0.00
	15	-0.15	-0.11	0.47	0.41	0.15	0.04	-9.8	-0.6	15.7	6.7	0.6	0.3	-5.68	-0.30	0.38	1.14	0.03	-0.00
	20	-0.29	-0.13	0.56	0.50	0.20	0.05	-11.6	-0.7	17.7	7.4	0.7	0.3	-5.63	-0.30	0.37	1.15	0.03	0.00
22	5	0.06	-0.07	0.58	0.09	0.09	0.02	-7.4	-0.2	13.9	3.0	0.4	0.1	-5.22	-0.47	0.33	1.15	0.04	-0.00
	10	0.00	-0.10	0.57	0.12	0.14	0.03	-8.6	-0.3	15.5	3.3	0.4	0.1	-5.18	-0.47	0.32	1.15	0.04	-0.00
	15	-0.13	-0.12	0.58	0.17	0.20	0.03	-9.6	-0.4	16.6	3.5	0.5	0.1	-5.22	-0.47	0.32	1.16	0.04	-0.00
	20	-0.27	-0.14	0.65	0.21	0.25	0.04	-10.7	-0.5	17.8	3.7	0.5	0.1	-5.26	-0.48	0.31	1.16	0.04	-0.00
23	5	0.07	-0.05	0.27	0.03	0.05	0.02	-6.7	-0.2	12.5	2.6	0.3	0.1	-3.17	-0.52	0.18	1.15	0.03	-0.00
	10	0.06	-0.08	0.25	0.04	0.09	0.02	-8.1	-0.3	13.8	2.8	0.4	0.1	-3.12	-0.54	0.17	1.15	0.03	-0.00
	15	0.02	-0.11	0.22	0.05	0.14	0.03	-9.4	-0.3	14.9	3.0	0.4	0.1	-3.11	-0.56	0.17	1.15	0.03	-0.00
	20	-0.03	-0.13	0.24	0.07	0.18	0.04	-10.5	-0.3	15.8	3.2	0.4	0.1	-3.12	-0.57	0.17	1.15	0.03	-0.00
24	5	0.07	-0.08	0.55	0.07	0.08	0.03	-8.2	-0.3	14.4	3.5	0.4	0.1	-4.26	-0.68	0.25	1.16	0.04	-0.00
	10	0.03	-0.12	0.54	0.10	0.13	0.04	-10.2	-0.4	16.5	3.9	0.5	0.1	-4.11	-0.71	0.24	1.16	0.04	-0.00
	15	-0.09	-0.16	0.50	0.14	0.20	0.05	-12.0	-0.5	18.1	4.2	0.6	0.1	-4.11	-0.73	0.24	1.16	0.04	-0.00
	20	-0.25	-0.19	0.59	0.19	0.26	0.05	-13.7	-0.6	19.6	4.5	0.6	0.2	-4.15	-0.74	0.23	1.16	0.04	-0.00
25	5	0.09	-0.08	0.37	0.18	0.09	0.02	-7.7	-0.3	12.0	3.9	0.4	0.1	-6.71	-0.59	0.32	1.14	0.04	-0.00
	10	0.03	-0.11	0.33	0.22	0.13	0.03	-9.2	-0.4	13.8	4.5	0.5	0.2	-6.79	-0.59	0.32	1.15	0.04	-0.00
	15	-0.07	-0.14	0.30	0.27	0.19	0.04	-10.6	-0.5	15.4	4.9	0.6	0.2	-6.82	-0.60	0.32	1.15	0.04	-0.00
	20	-0.22	-0.17	0.34	0.34	0.25	0.05	-11.9	-0.6	16.9	5.3	0.7	0.2	-6.89	-0.61	0.32	1.15	0.04	-0.00
26	5	-0.01	-0.06	0.71	0.33	0.03	0.01	-5.7	-0.4	9.9	4.2	0.6	0.3	-9.51	-0.43	0.53	1.12	0.04	0.00
	10	-0.07	-0.09	0.67	0.40	0.08	0.02	-7.2	-0.7	11.1	4.8	0.9	0.4	-9.50	-0.43	0.53	1.13	0.04	0.00
	15	-0.16	-0.12	0.63	0.47	0.14	0.03	-8.0	-1.0	12.0	5.2	1.2	0.5	-9.54	-0.44	0.52	1.13	0.04	0.00
	20	-0.29	-0.15	0.64	0.56	0.20	0.04	-8.7	-1.3	12.8	5.4	1.4	0.6	-9.61	-0.45	0.52	1.14	0.04	0.00
27	5	-0.06	-0.07	1.26	0.67	-0.01	-0.00	-6.3	-0.6	10.5	5.6	0.9	0.5	-7.87	-0.64	0.65	1.13	0.04	0.00
	10	-0.16	-0.10	1.34	0.85	0.03	-0.00	-7.4	-1.2	11.7	6.1	1.6	0.8	-7.70	-0.67	0.64	1.14	0.04	0.00
	15	-0.28	-0.13	1.43	1.04	0.08	0.01	-8.1	-1.8	12.5	6.3	2.2	1.1	-7.33	-0.71	0.63	1.14	0.04	0.00
	20	-0.42	-0.17	1.54	1.21	0.15	0.02	-8.7	-2.4	12.7	6.3	3.0	1.5	-7.27	-0.73	0.63	1.15	0.04	0.00

TABLE A(III)-9. FALL PLOW CORN, FALL FERTILIZATION (B SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.11	-0.05	5.59	0.45	-0.19	0.04	-9.0	-0.2	42.8	10.0	0.7	0.2	-0.05	-0.24	0.05	1.17	-0.00	-0.00
	10	-0.60	-0.07	7.83	0.86	-0.24	0.05	-16.0	-0.3	56.9	13.3	1.1	0.2	-0.05	-0.24	0.05	1.17	-0.00	-0.00
	15	-1.40	-0.10	10.35	1.40	-0.27	0.06	-25.2	-0.5	76.2	17.7	1.7	0.3	-0.08	-0.24	0.05	1.18	-0.00	-0.00
	20	-2.67	-0.12	13.47	2.15	-0.26	0.07	-36.3	-0.9	106.6	24.8	2.9	0.6	-0.13	-0.23	0.06	1.18	-0.00	-0.00
2	5	-0.03	-0.06	5.61	0.15	-0.17	0.05	-7.5	-0.3	35.1	7.0	1.0	0.2	0.05	-0.28	0.05	1.18	0.00	-0.00
	10	-0.28	-0.08	6.81	0.34	-0.18	0.06	-12.5	-0.5	44.8	9.0	1.6	0.3	0.06	-0.28	0.05	1.18	0.00	-0.00
	15	-0.69	-0.11	8.10	0.60	-0.17	0.07	-19.1	-0.7	56.7	11.4	2.3	0.4	0.08	-0.27	0.05	1.18	0.00	-0.00
	20	-1.27	-0.13	9.46	0.92	-0.14	0.08	-24.4	-0.9	69.2	13.8	3.1	0.5	0.05	-0.27	0.05	1.18	0.00	-0.00
3	5	0.02	-0.03	3.30	0.05	-0.10	0.02	-2.7	-0.1	18.6	2.3	0.6	0.1	-0.10	-0.51	0.05	1.17	-0.00	-0.00
	10	0.02	-0.04	3.83	0.06	-0.12	0.03	-3.8	-0.2	19.8	2.7	0.8	0.1	-0.03	-0.53	0.05	1.17	-0.00	-0.00
	15	0.01	-0.06	4.26	0.08	-0.13	0.03	-5.0	-0.3	20.4	3.0	0.9	0.1	-0.00	-0.54	0.05	1.17	-0.00	-0.00
	20	-0.02	-0.07	4.66	0.10	-0.14	0.04	-6.2	-0.4	21.0	3.3	1.0	0.2	0.03	-0.55	0.05	1.17	-0.00	-0.00
4	5	0.05	-0.04	4.42	0.16	-0.19	0.03	-4.0	-0.2	23.3	4.6	1.0	0.2	-0.34	-0.61	0.07	1.17	-0.00	-0.00
	10	-0.02	-0.06	5.71	0.27	-0.26	0.04	-6.2	-0.4	26.7	5.7	1.4	0.3	-0.24	-0.62	0.08	1.17	-0.00	-0.00
	15	-0.15	-0.08	6.94	0.40	-0.31	0.05	-9.2	-0.7	29.7	6.9	1.9	0.4	-0.20	-0.64	0.08	1.17	-0.00	-0.00
	20	-0.36	-0.11	8.16	0.57	-0.36	0.06	-12.7	-1.2	32.2	8.0	2.9	0.6	-0.16	-0.65	0.08	1.17	-0.00	-0.00
5	5	0.08	-0.03	3.66	0.08	-0.12	0.03	-3.0	-0.1	20.0	3.6	0.8	0.1	-0.98	-0.78	0.12	1.17	-0.00	-0.00
	10	0.07	-0.05	4.36	0.12	-0.15	0.04	-4.3	-0.3	22.2	4.2	1.0	0.2	-0.93	-0.79	0.12	1.17	-0.00	-0.00
	15	0.03	-0.07	5.05	0.18	-0.18	0.05	-6.1	-0.5	23.8	4.9	1.3	0.3	-0.87	-0.81	0.12	1.17	-0.00	-0.00
	20	-0.03	-0.09	5.68	0.24	-0.20	0.06	-8.5	-0.7	24.9	5.6	1.6	0.4	-0.90	-0.83	0.13	1.17	-0.00	-0.00
6	5	-0.18	-0.05	7.69	0.57	-0.51	0.02	-10.9	-0.4	42.0	10.0	1.4	0.3	-0.05	-0.79	0.06	1.18	-0.00	-0.00
	10	-0.75	-0.07	11.14	1.10	-0.70	0.02	-22.7	-1.0	57.3	15.2	2.4	0.6	0.48	-0.84	0.07	1.18	-0.00	-0.00
	15	-2.06	-0.07	14.60	1.92	-0.85	0.01	-39.7	-2.1	80.1	21.4	4.0	0.9	0.55	-0.84	0.07	1.18	-0.00	-0.00
	20	-4.29	-0.06	18.71	3.05	-0.97	-0.01	-63.2	-4.4	110.4	29.3	7.4	1.7	0.64	-0.84	0.07	1.18	-0.00	-0.00
7	5	-0.10	-0.05	6.74	0.50	-0.44	0.02	-6.3	-0.3	25.1	7.0	1.1	0.3	-1.74	-0.71	0.12	1.17	-0.01	-0.00
	10	-0.40	-0.07	9.08	0.86	-0.58	0.02	-11.0	-0.9	30.9	9.6	2.0	0.6	-1.55	-0.74	0.13	1.17	-0.01	-0.00
	15	-1.04	-0.08	11.60	1.40	-0.73	0.01	-17.5	-1.6	38.5	12.5	3.2	0.9	-1.47	-0.75	0.14	1.17	-0.01	-0.00
	20	-2.06	-0.09	13.82	2.05	-0.81	0.01	-25.7	-3.0	48.5	15.7	5.3	1.4	-1.46	-0.76	0.14	1.17	-0.01	-0.00
8	5	0.03	-0.03	3.26	0.15	-0.15	0.02	-2.9	-0.1	16.1	3.5	0.7	0.1	-2.94	-0.71	0.15	1.16	-0.01	-0.00
	10	-0.00	-0.04	3.89	0.21	-0.18	0.03	-3.9	-0.2	18.0	4.1	0.9	0.2	-2.90	-0.72	0.15	1.16	-0.01	-0.00
	15	-0.06	-0.06	4.44	0.28	-0.20	0.04	-5.1	-0.4	19.3	4.6	1.1	0.2	-2.85	-0.74	0.15	1.16	-0.01	-0.00
	20	-0.13	-0.07	5.02	0.35	-0.23	0.04	-6.5	-0.6	20.1	5.2	1.4	0.3	-2.85	-0.76	0.16	1.16	-0.01	-0.00
9	5	-0.49	-0.05	7.88	1.12	-0.51	-0.01	-15.5	-1.0	39.7	13.2	1.9	0.7	-17.86	-0.13	0.43	1.16	-0.03	0.00
	10	-1.42	-0.07	10.11	1.82	-0.61	-0.02	-34.4	-2.4	54.5	21.2	3.4	1.3	-18.74	-0.03	0.45	1.16	-0.03	0.00
	15	-3.70	-0.08	12.96	3.05	-0.68	-0.03	-55.6	-5.4	72.0	28.4	7.0	2.5	-19.59	0.02	0.47	1.17	-0.03	0.00
	20	-7.48	-0.08	16.71	4.72	-0.66	-0.04	-71.1	-8.2	86.0	33.5	10.5	3.7	-20.27	0.04	0.49	1.17	-0.03	0.00

TABLE A(III)-9 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.29	-0.04	4.71	0.85	-0.24	-0.00	-8.8	-0.4	28.0	10.3	1.1	0.4	-17.28	-0.01	0.48	1.15	-0.02	0.00
	10	-0.65	-0.06	6.34	1.28	-0.31	0.00	-17.0	-1.1	35.4	14.8	1.7	0.7	-17.65	0.05	0.48	1.16	-0.02	0.00
	15	-1.35	-0.09	7.41	1.81	-0.32	0.01	-28.5	-2.1	43.5	19.9	2.7	1.2	-18.03	0.10	0.48	1.16	-0.02	0.00
	20	-2.65	-0.15	8.58	2.55	-0.30	0.03	-43.8	-4.1	56.3	26.3	5.2	2.1	-18.48	0.14	0.49	1.17	-0.02	0.00
11	5	-0.11	-0.04	2.91	0.59	-0.12	0.01	-5.5	-0.2	18.6	7.7	0.6	0.2	-11.09	-0.35	0.42	1.15	-0.02	-0.00
	10	-0.22	-0.05	3.55	0.77	-0.15	0.02	-8.8	-0.3	22.9	10.2	0.8	0.3	-11.09	-0.32	0.42	1.15	-0.02	0.00
	15	-0.42	-0.07	4.30	1.01	-0.17	0.03	-13.4	-0.6	26.5	12.8	1.0	0.4	-11.04	-0.32	0.43	1.16	-0.02	0.00
	20	-0.79	-0.10	5.08	1.34	-0.19	0.04	-19.4	-0.9	31.0	15.9	1.3	0.6	-11.06	-0.33	0.43	1.16	-0.02	0.00
12	5	-0.01	-0.03	2.61	0.21	-0.13	0.02	-3.2	-0.1	13.4	4.0	0.6	0.2	-3.95	-0.45	0.19	1.15	-0.01	-0.00
	10	-0.04	-0.04	3.03	0.27	-0.15	0.03	-4.0	-0.2	15.0	4.6	0.8	0.2	-4.03	-0.45	0.20	1.15	-0.01	-0.00
	15	-0.10	-0.06	3.45	0.34	-0.17	0.04	-5.1	-0.4	16.3	5.2	1.0	0.3	-4.04	-0.46	0.20	1.15	-0.01	-0.00
	20	-0.19	-0.07	3.91	0.43	-0.19	0.05	-6.5	-0.5	17.1	5.9	1.2	0.4	-4.03	-0.47	0.20	1.16	-0.01	-0.00
13	5	-0.02	-0.03	1.53	0.27	-0.02	0.02	-3.3	-0.1	12.4	4.8	0.3	0.1	-7.90	-0.22	0.41	1.13	-0.01	0.00
	10	-0.06	-0.04	1.81	0.34	-0.02	0.03	-4.3	-0.1	14.3	5.7	0.4	0.2	-7.95	-0.21	0.42	1.14	-0.01	0.00
	15	-0.12	-0.05	2.09	0.42	-0.03	0.03	-5.5	-0.2	16.0	6.6	0.5	0.2	-7.95	-0.21	0.42	1.14	-0.01	0.00
	20	-0.20	-0.06	2.35	0.51	-0.03	0.04	-7.0	-0.2	17.5	7.5	0.5	0.2	-7.94	-0.21	0.42	1.14	-0.01	0.00
14	5	-0.01	-0.03	1.37	0.27	-0.01	0.02	-3.6	-0.1	12.9	5.1	0.3	0.1	-8.02	-0.27	0.40	1.13	-0.01	-0.00
	10	-0.05	-0.04	1.69	0.35	-0.02	0.03	-4.8	-0.1	15.0	6.2	0.4	0.1	-8.04	-0.26	0.40	1.14	-0.01	0.00
	15	-0.12	-0.05	1.98	0.43	-0.02	0.03	-6.2	-0.2	16.8	7.2	0.4	0.2	-8.01	-0.26	0.40	1.14	-0.01	0.00
	20	-0.20	-0.06	2.27	0.52	-0.03	0.04	-8.0	-0.2	18.4	8.2	0.4	0.2	-7.96	-0.26	0.40	1.15	-0.01	0.00
15	5	0.01	-0.03	1.24	0.32	-0.03	0.01	-2.8	-0.1	9.3	4.3	0.5	0.2	-5.57	-0.45	0.31	1.13	-0.01	-0.00
	10	-0.01	-0.04	1.54	0.37	-0.04	0.02	-3.6	-0.2	10.4	5.0	0.6	0.3	-5.53	-0.46	0.31	1.13	-0.01	-0.00
	15	-0.03	-0.05	1.81	0.43	-0.05	0.03	-4.3	-0.4	11.0	5.5	0.8	0.4	-5.41	-0.47	0.31	1.14	-0.01	0.00
	20	-0.06	-0.07	2.06	0.50	-0.05	0.04	-5.1	-0.6	11.3	5.9	1.0	0.5	-5.35	-0.49	0.31	1.14	-0.01	0.00
16	5	0.04	-0.03	3.08	0.13	-0.07	0.02	-2.6	-0.1	18.9	3.6	0.5	0.1	-3.36	-0.54	0.20	1.16	-0.00	-0.00
	10	0.02	-0.04	3.52	0.17	-0.08	0.03	-3.9	-0.1	21.2	4.3	0.6	0.1	-3.31	-0.55	0.21	1.16	-0.00	-0.00
	15	-0.02	-0.05	3.93	0.21	-0.09	0.04	-5.5	-0.2	23.0	4.9	0.6	0.1	-3.34	-0.56	0.21	1.16	-0.00	-0.00
	20	-0.08	-0.07	4.35	0.27	-0.10	0.05	-7.5	-0.3	24.2	5.6	0.8	0.2	-3.37	-0.58	0.21	1.16	-0.00	-0.00
17	5	0.04	-0.02	2.84	0.11	-0.07	0.02	-2.0	-0.1	16.3	2.9	0.5	0.1	-3.67	-0.74	0.20	1.16	-0.00	-0.00
	10	0.03	-0.04	3.27	0.13	-0.08	0.03	-2.8	-0.1	18.0	3.4	0.6	0.1	-3.52	-0.77	0.20	1.16	-0.00	-0.00
	15	0.01	-0.05	3.68	0.16	-0.09	0.04	-3.9	-0.2	19.2	3.8	0.7	0.1	-3.55	-0.79	0.21	1.16	-0.00	-0.00
	20	-0.03	-0.07	4.06	0.21	-0.10	0.05	-5.3	-0.3	20.4	4.3	0.8	0.2	-3.57	-0.81	0.21	1.16	-0.00	-0.00
18	5	-0.03	-0.02	1.67	0.16	-0.01	0.01	-2.1	-0.0	13.7	3.1	0.3	0.1	-9.04	-0.21	0.37	1.14	-0.01	-0.00
	10	-0.06	-0.02	1.97	0.20	-0.02	0.02	-2.7	-0.1	15.1	3.5	0.3	0.1	-9.03	-0.20	0.37	1.14	-0.01	-0.00
	15	-0.10	-0.03	2.23	0.24	-0.03	0.03	-3.4	-0.1	16.3	3.9	0.4	0.1	-9.06	-0.20	0.38	1.15	-0.01	-0.00
	20	-0.15	-0.04	2.50	0.29	-0.03	0.03	-4.4	-0.1	17.3	4.4	0.4	0.1	-9.09	-0.21	0.38	1.15	-0.01	0.00

TABLE A(III)-9 (CONT)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
19	5	-0.01	-0.03	2.15	0.20	-0.05	0.02	-3.1	-0.1	13.2	4.0	0.3	0.1	-7.94	-0.35	0.32	1.14	-0.01	-0.00
	10	-0.04	-0.04	2.37	0.24	-0.05	0.03	-4.0	-0.1	14.8	4.6	0.4	0.1	-8.01	-0.35	0.32	1.14	-0.01	-0.00
	15	-0.09	-0.05	2.55	0.29	-0.05	0.04	-5.0	-0.2	16.0	5.2	0.4	0.1	-8.05	-0.36	0.33	1.15	-0.01	-0.00
	20	-0.14	-0.06	2.74	0.34	-0.05	0.04	-6.2	-0.2	17.2	5.8	0.5	0.2	-8.05	-0.37	0.33	1.15	-0.01	-0.00
20	5	0.02	-0.03	2.08	0.25	-0.07	0.02	-3.5	-0.1	12.8	4.7	0.4	0.1	-6.16	-0.35	0.29	1.14	-0.01	-0.00
	10	-0.02	-0.04	2.36	0.30	-0.08	0.03	-4.7	-0.2	14.8	5.6	0.5	0.2	-6.18	-0.34	0.29	1.14	-0.01	-0.00
	15	-0.07	-0.05	2.61	0.38	-0.08	0.04	-6.1	-0.2	16.4	6.5	0.5	0.2	-6.14	-0.35	0.29	1.15	-0.01	-0.00
	20	-0.15	-0.07	2.87	0.47	-0.09	0.04	-7.8	-0.3	17.9	7.5	0.6	0.2	-6.13	-0.35	0.29	1.15	-0.01	-0.00
21	5	0.01	-0.03	1.83	0.27	-0.07	0.02	-3.2	-0.1	10.9	4.6	0.4	0.1	-5.70	-0.30	0.27	1.13	-0.01	-0.00
	10	-0.02	-0.04	2.07	0.33	-0.07	0.03	-4.2	-0.2	12.4	5.4	0.5	0.2	-5.73	-0.30	0.27	1.14	-0.01	-0.00
	15	-0.07	-0.05	2.28	0.40	-0.08	0.04	-5.3	-0.3	13.7	6.2	0.6	0.3	-5.68	-0.30	0.27	1.14	-0.01	-0.00
	20	-0.14	-0.07	2.49	0.48	-0.08	0.04	-6.6	-0.4	14.7	7.0	0.8	0.3	-5.63	-0.30	0.27	1.15	-0.01	0.00
22	5	0.04	-0.02	3.21	0.09	-0.14	0.01	-1.4	-0.0	14.4	2.1	0.4	0.1	-5.22	-0.47	0.24	1.15	-0.01	-0.00
	10	0.03	-0.03	3.55	0.11	-0.15	0.02	-1.8	-0.1	15.5	2.3	0.5	0.1	-5.18	-0.47	0.24	1.15	-0.01	-0.00
	15	0.01	-0.03	3.86	0.13	-0.16	0.02	-2.4	-0.1	16.0	2.5	0.6	0.1	-5.22	-0.47	0.24	1.16	-0.01	-0.00
	20	-0.01	-0.04	4.19	0.16	-0.18	0.03	-3.2	-0.2	16.4	2.8	0.6	0.1	-5.26	-0.48	0.24	1.16	-0.01	-0.00
23	5	0.04	-0.01	1.77	0.03	-0.00	0.01	-1.4	-0.0	13.1	1.8	0.3	0.0	-3.17	-0.52	0.17	1.15	0.00	-0.00
	10	0.04	-0.02	1.91	0.04	-0.00	0.02	-1.9	-0.1	13.9	2.0	0.4	0.0	-3.12	-0.54	0.17	1.15	0.00	-0.00
	15	0.04	-0.03	2.04	0.04	-0.00	0.02	-2.4	-0.1	14.3	2.1	0.4	0.1	-3.11	-0.56	0.17	1.15	0.00	-0.00
	20	0.03	-0.04	2.17	0.05	-0.00	0.02	-3.1	-0.1	14.6	2.3	0.4	0.1	-3.12	-0.57	0.17	1.15	0.00	-0.00
24	5	0.03	-0.02	2.87	0.08	-0.08	0.02	-1.9	-0.1	15.5	2.5	0.5	0.1	-4.26	-0.68	0.20	1.16	-0.00	-0.00
	10	0.02	-0.03	3.20	0.09	-0.09	0.02	-2.7	-0.1	16.9	2.8	0.6	0.1	-4.11	-0.71	0.20	1.16	-0.01	-0.00
	15	0.01	-0.04	3.51	0.11	-0.09	0.03	-3.6	-0.2	17.7	3.2	0.7	0.1	-4.11	-0.73	0.20	1.16	-0.01	-0.00
	20	-0.03	-0.06	3.82	0.14	-0.10	0.04	-4.7	-0.3	18.3	3.5	0.8	0.1	-4.15	-0.74	0.21	1.16	-0.01	-0.00
25	5	0.04	-0.02	2.41	0.18	-0.10	0.02	-2.0	-0.1	12.4	3.1	0.4	0.1	-6.71	-0.59	0.25	1.14	-0.01	-0.00
	10	0.03	-0.03	2.70	0.22	-0.11	0.02	-2.7	-0.1	13.7	3.6	0.6	0.1	-6.79	-0.59	0.25	1.15	-0.01	-0.00
	15	0.00	-0.05	2.98	0.25	-0.12	0.03	-3.6	-0.2	14.6	4.0	0.7	0.2	-6.82	-0.60	0.25	1.15	-0.01	-0.00
	20	-0.03	-0.06	3.25	0.30	-0.13	0.04	-4.6	-0.3	15.3	4.4	0.8	0.2	-6.89	-0.61	0.25	1.15	-0.01	-0.00
26	5	-0.03	-0.03	2.34	0.33	-0.14	0.01	-2.7	-0.2	9.9	3.8	0.6	0.2	-9.51	-0.43	0.31	1.12	-0.02	0.00
	10	-0.06	-0.04	2.70	0.39	-0.16	0.02	-3.4	-0.3	10.7	4.3	0.9	0.3	-9.50	-0.43	0.32	1.13	-0.02	0.00
	15	-0.09	-0.06	3.02	0.45	-0.17	0.03	-4.1	-0.5	11.0	4.6	1.2	0.5	-9.54	-0.44	0.32	1.13	-0.02	0.00
	20	-0.15	-0.07	3.32	0.53	-0.18	0.04	-4.9	-0.8	11.2	4.9	1.4	0.6	-9.61	-0.45	0.32	1.14	-0.02	0.00
27	5	-0.05	-0.03	1.98	0.67	-0.09	-0.01	-3.2	-0.3	10.7	5.2	0.9	0.4	-7.87	-0.64	0.34	1.13	-0.01	0.00
	10	-0.10	-0.05	2.61	0.84	-0.13	-0.01	-4.2	-0.7	11.2	5.7	1.4	0.7	-7.70	-0.67	0.34	1.14	-0.01	0.00
	15	-0.17	-0.08	3.26	1.01	-0.16	0.00	-5.2	-1.2	10.9	6.1	2.0	1.1	-7.33	-0.71	0.33	1.14	-0.01	0.00
	20	-0.26	-0.12	3.84	1.18	-0.18	0.02	-6.0	-2.0	10.1	6.1	3.0	1.5	-7.27	-0.73	0.33	1.15	-0.01	0.00

TABLE A(III)-10. FALL PLOW CORN (C SOIL ONLY)

REGION	AW	A	B	A'	B'
1	5	0.69	13.29	-0.63	35.52
	10	0.62	13.13	-0.51	23.98
	15	0.57	12.69	-0.43	15.84
	20	0.51	12.29	-0.38	8.85
2	5	1.09	16.05	-1.05	38.01
	10	1.02	16.00	-0.93	27.86
	15	0.96	15.84	-0.82	20.57
	20	0.89	15.69	-0.75	15.36
3	5	1.50	20.28	-1.49	47.80
	10	1.54	19.93	-1.53	42.39
	15	1.54	19.74	-1.54	39.30
	20	1.53	19.49	-1.53	36.81
4	5	1.60	13.35	-1.57	46.03
	10	1.63	12.95	-1.53	36.72
	15	1.60	12.67	-1.44	30.23
	20	1.56	12.37	-1.44	25.39
5	5	1.54	16.23	-1.52	46.35
	10	1.57	16.03	-1.49	38.66
	15	1.56	15.72	-1.49	33.64
	20	1.56	15.43	-1.48	29.58
6	5	1.12	7.18	-1.03	36.94
	10	1.06	6.86	-0.81	23.21
	15	0.98	6.71	-0.65	14.92
	20	0.90	6.51	-0.54	8.83
7	5	1.60	7.20	-1.53	44.67
	10	1.64	6.76	-1.41	31.68
	15	1.61	6.35	-1.22	23.19
	20	1.57	6.05	-1.06	16.58
8	5	1.62	16.42	-1.58	47.88
	10	1.68	16.06	-1.59	40.03
	15	1.70	15.74	-1.56	34.78
	20	1.70	15.35	-1.56	30.89
9	5	1.49	5.18	-1.37	38.81
	10	1.39	4.73	-1.03	23.65
	15	1.33	4.36	-0.94	15.74
	20	1.26	4.05	-0.85	10.62
10	5	1.45	11.51	-1.38	43.21
	10	1.41	11.21	-1.14	29.10
	15	1.33	10.63	-1.01	20.73
	20	1.28	10.07	-0.89	13.92
11	5	1.31	18.29	-1.26	44.68
	10	1.25	18.06	-1.04	32.34
	15	1.23	17.55	-0.91	24.71
	20	1.20	17.03	-0.82	18.76
12	5	1.70	17.26	-1.67	49.86
	10	1.76	16.91	-1.68	41.67
	15	1.79	16.61	-1.64	36.12
	20	1.79	16.18	-1.58	31.72
13	5	1.23	29.36	-1.19	42.36
	10	1.22	29.26	-1.08	33.79
	15	1.20	28.99	-0.95	28.10
	20	1.18	28.66	-0.85	23.63
14	5	1.06	30.32	-1.02	39.71
	10	1.07	30.05	-0.90	30.99
	15	1.06	29.72	-0.80	25.40
	20	1.01	29.36	-0.71	21.00
15	5	1.78	23.50	-1.76	45.86
	10	1.82	23.11	-1.75	38.20
	15	1.84	22.70	-1.76	33.72
	20	1.84	22.30	-1.77	30.42
16	5	1.12	21.32	-1.09	44.55
	10	1.10	21.09	-1.02	37.28
	15	1.08	20.86	-0.97	32.07
	20	1.07	20.56	-0.98	28.35
17	5	1.34	20.23	-1.32	46.89
	10	1.36	19.99	-1.30	39.98
	15	1.34	19.72	-1.28	35.24
	20	1.34	19.45	-1.27	31.19
18	5	0.95	29.66	-0.94	42.44
	10	0.94	29.49	-0.90	35.99
	15	0.92	29.22	-0.86	31.46
	20	0.90	28.85	-0.86	27.81
19	5	1.13	25.98	-1.10	42.15
	10	1.13	25.77	-1.04	35.15
	15	1.10	25.51	-0.97	30.35
	20	1.08	25.17	-0.95	26.59
20	5	1.16	26.38	-1.13	42.34
	10	1.17	26.13	-1.06	33.89
	15	1.16	25.84	-0.98	28.25
	20	1.12	25.56	-0.88	23.60
21	5	1.37	26.47	-1.35	43.38
	10	1.41	26.13	-1.32	35.28
	15	1.40	25.75	-1.26	29.86
	20	1.38	25.41	-1.22	25.76
22	5	1.31	21.82	-1.30	48.53
	10	1.33	21.58	-1.31	43.07
	15	1.32	21.42	-1.32	39.79
	20	1.33	21.12	-1.32	37.20
23	5	1.16	33.75	-1.15	43.86
	10	1.18	33.54	-1.15	39.55
	15	1.20	33.36	-1.19	36.84
	20	1.20	33.15	-1.19	34.62
24	5	1.36	22.20	-1.35	46.96
	10	1.37	21.94	-1.33	40.77
	15	1.37	21.70	-1.34	36.99
	20	1.36	21.46	-1.34	34.04
25	5	1.52	22.22	-1.50	48.96
	10	1.53	22.05	-1.48	41.61
	15	1.55	21.72	-1.50	36.73
	20	1.55	21.37	-1.49	32.99
26	5	2.23	14.09	-2.21	53.61
	10	2.30	13.61	-2.25	45.53
	15	2.35	13.08	-2.30	41.15
	20	2.36	12.75	-2.32	37.84
27	5	2.58	8.51	-2.56	53.81
	10	2.66	7.82	-2.61	45.33
	15	2.74	7.07	-2.63	40.18
	20	2.79	6.36	-2.66	36.45

TABLE A(III)-11. FALL PLOW CORN, SPRING FERTILIZATION (C SOIL ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.70	-0.07	3.43	0.70	0.13	0.03	-18.8	-0.3	56.5	12.5	1.1	0.2	-0.27	-0.15	0.37	1.17	0.03	-0.00
	10	-2.02	-0.07	5.78	1.36	0.22	0.04	-25.2	-0.5	76.9	17.0	1.6	0.4	-0.27	-0.15	0.37	1.18	0.02	-0.00
	15	-3.26	-0.09	8.91	2.12	0.33	0.06	-35.3	-1.0	108.5	23.9	2.9	0.7	-0.30	-0.14	0.36	1.18	0.02	-0.00
	20	-4.86	-0.10	13.66	3.16	0.43	0.07	-54.0	-2.2	167.1	36.8	7.0	1.6	-0.34	-0.14	0.36	1.18	0.02	-0.00
2	5	-0.30	-0.09	1.70	0.28	0.17	0.04	-15.5	-0.5	46.8	8.6	1.6	0.3	-0.20	-0.20	0.20	1.18	0.04	-0.00
	10	-1.07	-0.10	2.78	0.58	0.29	0.05	-19.8	-0.8	61.2	11.2	2.5	0.5	-0.21	-0.20	0.20	1.18	0.03	-0.00
	15	-1.77	-0.12	4.38	0.93	0.42	0.07	-25.5	-1.3	79.3	14.5	3.9	0.7	-0.21	-0.19	0.19	1.18	0.03	-0.00
	20	-2.52	-0.13	6.53	1.34	0.51	0.08	-31.7	-2.0	99.0	18.1	6.1	1.2	-0.23	-0.19	0.18	1.18	0.03	-0.00
3	5	0.01	-0.07	1.08	0.09	0.09	0.02	-9.7	-0.6	22.6	3.5	1.0	0.2	-0.41	-0.39	0.18	1.17	0.04	-0.00
	10	-0.09	-0.11	1.09	0.13	0.17	0.03	-12.1	-0.9	25.7	3.9	1.4	0.2	-0.36	-0.40	0.17	1.17	0.04	-0.00
	15	-0.21	-0.15	1.20	0.17	0.25	0.04	-14.0	-1.0	27.7	4.2	1.5	0.2	-0.35	-0.41	0.17	1.17	0.04	-0.00
	20	-0.37	-0.18	1.39	0.21	0.32	0.05	-15.7	-1.1	29.6	4.5	1.6	0.3	-0.33	-0.42	0.16	1.17	0.04	-0.00
4	5	-0.04	-0.10	1.41	0.25	0.12	0.03	-13.3	-1.0	28.0	6.2	1.5	0.3	-0.51	-0.47	0.24	1.17	0.04	-0.00
	10	-0.43	-0.14	1.64	0.45	0.24	0.04	-18.2	-1.6	34.8	7.5	2.3	0.5	-0.45	-0.48	0.23	1.17	0.05	-0.00
	15	-0.99	-0.20	2.23	0.68	0.34	0.06	-23.6	-2.2	41.5	8.9	3.2	0.7	-0.44	-0.49	0.21	1.17	0.05	-0.00
	20	-1.76	-0.26	3.19	0.95	0.46	0.07	-27.7	-3.1	46.8	9.9	4.9	1.1	-0.42	-0.50	0.20	1.18	0.05	-0.00
5	5	0.10	-0.09	0.86	0.13	0.10	0.03	-12.5	-0.8	23.3	5.2	1.1	0.2	-1.27	-0.60	0.19	1.17	0.04	-0.00
	10	-0.09	-0.14	0.92	0.23	0.20	0.04	-16.0	-1.2	27.9	6.1	1.6	0.4	-1.24	-0.61	0.18	1.17	0.04	-0.00
	15	-0.35	-0.19	1.14	0.33	0.29	0.06	-19.4	-1.7	31.7	6.9	2.3	0.5	-1.21	-0.63	0.17	1.17	0.04	-0.00
	20	-0.69	-0.24	1.54	0.44	0.38	0.07	-22.8	-2.3	35.4	7.6	3.0	0.7	-1.23	-0.64	0.17	1.17	0.05	-0.00
6	5	-0.60	-0.09	5.57	0.84	-0.09	0.02	-27.7	-1.3	50.3	12.8	2.0	0.5	-0.26	-0.59	0.52	1.18	0.03	-0.00
	10	-2.46	-0.11	7.34	1.71	0.00	0.01	-46.9	-2.8	76.9	19.1	4.0	1.0	-0.03	-0.60	0.50	1.18	0.04	-0.00
	15	-5.52	-0.12	11.17	2.89	0.08	0.01	-72.4	-5.2	111.5	27.6	7.5	1.9	0.01	-0.59	0.48	1.18	0.04	-0.00
	20	-9.80	-0.13	16.84	4.42	0.14	0.01	-104.3	-9.9	155.9	38.0	14.7	3.7	0.03	-0.58	0.47	1.18	0.04	-0.00
7	5	-0.25	-0.09	3.82	0.67	-0.07	0.02	-15.7	-1.0	28.8	8.7	1.6	0.5	-1.42	-0.59	0.49	1.17	0.04	-0.00
	10	-1.08	-0.12	4.30	1.18	0.04	0.02	-23.4	-2.3	39.6	11.6	3.3	0.9	-1.31	-0.61	0.47	1.17	0.04	-0.00
	15	-2.48	-0.16	5.76	1.86	0.13	0.03	-32.5	-3.8	51.4	14.8	5.4	1.5	-1.25	-0.62	0.45	1.18	0.04	-0.00
	20	-4.34	-0.22	8.05	2.64	0.26	0.04	-42.4	-6.9	63.6	18.1	9.9	2.9	-1.27	-0.63	0.44	1.18	0.05	-0.00
8	5	0.03	-0.08	0.63	0.21	0.10	0.03	-11.5	-0.6	18.6	5.0	0.9	0.2	-2.64	-0.57	0.21	1.16	0.04	-0.00
	10	-0.15	-0.12	0.62	0.31	0.18	0.04	-14.0	-1.0	22.1	5.8	1.3	0.4	-2.61	-0.58	0.20	1.17	0.04	-0.00
	15	-0.40	-0.17	0.75	0.43	0.27	0.05	-16.4	-1.4	25.1	6.5	1.8	0.5	-2.58	-0.60	0.19	1.17	0.05	-0.00
	20	-0.70	-0.21	1.02	0.55	0.34	0.06	-18.5	-1.9	27.7	7.1	2.3	0.6	-2.57	-0.61	0.19	1.17	0.05	-0.00
9	5	-1.02	-0.12	1.77	1.57	0.18	-0.01	-33.7	-2.2	44.0	16.3	2.5	0.9	-14.94	-0.29	0.63	1.16	0.03	0.00
	10	-3.33	-0.12	3.18	2.71	0.28	-0.03	-56.9	-4.7	69.9	24.9	5.2	1.9	-15.43	-0.23	0.64	1.17	0.03	0.00
	15	-7.43	-0.12	6.96	4.48	0.35	-0.04	-76.2	-9.0	91.4	31.9	10.1	3.7	-15.99	-0.22	0.65	1.17	0.03	0.00
	20	-12.96	-0.21	12.78	6.69	0.49	-0.01	-94.1	-10.4	110.7	38.0	12.4	4.3	-16.64	-0.20	0.68	1.17	0.03	0.00

TABLE A(III)-11 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.49	-0.09	1.34	1.10	0.13	0.00	-23.0	-1.3	30.1	13.2	1.4	0.6	-15.08	-0.12	0.66	1.16	0.02	0.00
	10	-1.52	-0.13	1.72	1.76	0.21	0.01	-35.9	-2.6	44.4	18.7	2.8	1.2	-15.42	-0.07	0.67	1.16	0.02	0.00
	15	-3.25	-0.17	2.82	2.61	0.34	0.02	-50.0	-5.0	60.0	24.5	5.2	2.3	-15.69	-0.04	0.68	1.17	0.02	0.00
	20	-5.59	-0.29	4.89	3.69	0.51	0.07	-66.1	-10.3	78.2	31.0	10.7	4.6	-16.10	-0.01	0.70	1.17	0.02	0.00
11	5	-0.18	-0.08	0.84	0.75	0.09	0.02	-15.6	-0.7	21.0	10.1	0.8	0.4	-10.35	-0.30	0.53	1.15	0.02	0.00
	10	-0.56	-0.11	0.96	1.03	0.15	0.03	-23.5	-1.2	29.5	13.7	1.3	0.6	-10.35	-0.27	0.53	1.16	0.02	0.00
	15	-1.20	-0.15	1.34	1.41	0.23	0.04	-31.7	-1.8	38.6	17.4	1.8	0.9	-10.30	-0.27	0.53	1.16	0.02	0.00
	20	-2.14	-0.21	2.19	1.91	0.32	0.06	-42.0	-2.8	49.5	21.9	2.7	1.4	-10.26	-0.28	0.53	1.17	0.02	0.00
12	5	-0.02	-0.06	1.54	0.28	0.02	0.02	-8.1	-0.5	15.5	5.1	0.8	0.2	-3.83	-0.37	0.49	1.16	0.03	-0.00
	10	-0.15	-0.09	1.51	0.37	0.08	0.03	-10.1	-0.9	18.4	5.9	1.3	0.4	-3.87	-0.37	0.48	1.16	0.03	-0.00
	15	-0.35	-0.12	1.61	0.49	0.15	0.04	-12.4	-1.3	21.3	6.7	1.7	0.5	-3.89	-0.37	0.48	1.16	0.03	-0.00
	20	-0.61	-0.16	1.84	0.62	0.22	0.06	-14.9	-1.6	24.1	7.4	2.1	0.7	-3.90	-0.38	0.47	1.16	0.03	0.00
13	5	-0.04	-0.05	0.41	0.35	0.07	0.02	-9.4	-0.5	15.4	6.4	0.6	0.2	-7.46	-0.18	0.47	1.14	0.02	0.00
	10	-0.17	-0.08	0.43	0.45	0.12	0.03	-13.1	-0.7	19.7	8.0	0.8	0.3	-7.50	-0.17	0.47	1.15	0.02	0.00
	15	-0.37	-0.11	0.56	0.58	0.17	0.04	-16.5	-0.9	23.9	9.4	0.9	0.4	-7.50	-0.17	0.47	1.15	0.02	0.00
	20	-0.63	-0.14	0.80	0.72	0.22	0.05	-20.3	-0.9	28.3	10.9	0.9	0.4	-7.50	-0.17	0.47	1.15	0.02	0.00
14	5	-0.03	-0.05	0.36	0.36	0.06	0.02	-10.7	-0.5	16.2	7.1	0.5	0.2	-7.66	-0.21	0.41	1.14	0.02	0.00
	10	-0.18	-0.08	0.39	0.48	0.11	0.03	-15.0	-0.7	21.2	8.9	0.7	0.3	-7.68	-0.21	0.41	1.15	0.02	0.00
	15	-0.41	-0.12	0.54	0.62	0.17	0.04	-19.0	-0.8	25.8	10.6	0.8	0.4	-7.66	-0.21	0.41	1.15	0.02	0.00
	20	-0.68	-0.16	0.78	0.77	0.23	0.06	-23.3	-0.9	30.8	12.5	0.8	0.4	-7.63	-0.21	0.41	1.16	0.02	0.00
15	5	0.02	-0.05	0.47	0.41	0.05	0.02	-6.4	-0.6	10.8	5.3	0.7	0.3	-5.44	-0.38	0.39	1.14	0.03	-0.00
	10	-0.03	-0.08	0.44	0.49	0.10	0.03	-8.2	-0.9	12.9	6.2	1.1	0.5	-5.41	-0.38	0.39	1.14	0.03	0.00
	15	-0.11	-0.11	0.46	0.58	0.15	0.04	-9.3	-1.3	14.4	6.7	1.5	0.7	-5.33	-0.39	0.38	1.15	0.03	0.00
	20	-0.21	-0.15	0.52	0.68	0.21	0.06	-10.6	-1.7	15.6	7.0	1.9	1.0	-5.27	-0.41	0.38	1.15	0.03	0.00
16	5	0.03	-0.07	1.13	0.18	0.07	0.03	-12.1	-0.5	22.7	5.4	0.7	0.2	-3.43	-0.39	0.34	1.16	0.03	-0.00
	10	-0.15	-0.11	1.20	0.26	0.14	0.04	-16.5	-0.7	27.6	6.5	0.9	0.2	-3.42	-0.40	0.34	1.17	0.03	-0.00
	15	-0.39	-0.15	1.49	0.35	0.22	0.05	-20.8	-0.8	32.1	7.5	1.0	0.2	-3.45	-0.41	0.33	1.17	0.03	-0.00
	20	-0.68	-0.20	1.86	0.44	0.29	0.06	-24.3	-1.0	35.8	8.3	1.3	0.3	-3.49	-0.42	0.33	1.17	0.03	-0.00
17	5	0.06	-0.08	0.76	0.15	0.08	0.02	-11.1	-0.5	18.0	4.7	0.7	0.2	-3.58	-0.56	0.25	1.16	0.03	-0.00
	10	-0.08	-0.12	0.78	0.22	0.15	0.04	-13.9	-0.7	21.3	5.4	0.9	0.2	-3.49	-0.58	0.24	1.16	0.03	-0.00
	15	-0.28	-0.17	0.84	0.29	0.23	0.05	-16.6	-0.9	24.2	6.1	1.1	0.3	-3.52	-0.59	0.24	1.17	0.03	-0.00
	20	-0.52	-0.21	1.09	0.37	0.30	0.06	-19.5	-1.1	27.2	6.8	1.3	0.4	-3.55	-0.61	0.23	1.17	0.04	-0.00
18	5	-0.09	-0.05	0.54	0.23	0.06	0.02	-9.7	-0.3	15.3	5.0	0.4	0.1	-8.58	-0.16	0.40	1.15	0.02	0.00
	10	-0.28	-0.08	0.61	0.31	0.11	0.03	-12.5	-0.5	18.3	5.8	0.5	0.2	-8.58	-0.16	0.39	1.15	0.02	0.00
	15	-0.55	-0.10	0.69	0.41	0.16	0.03	-15.2	-0.6	21.1	6.5	0.5	0.2	-8.62	-0.16	0.39	1.16	0.02	0.00
	20	-0.83	-0.12	0.91	0.51	0.21	0.04	-17.9	-0.7	23.8	7.2	0.6	0.2	-8.65	-0.16	0.39	1.16	0.02	0.00

TABLE A(III)-11 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.04	-0.06	0.20	0.27	0.08	0.02	-10.8	-0.5	15.8	5.9	0.5	0.2	-7.37	-0.28	0.30	1.15	0.02	-0.00
	10	-0.22	-0.09	0.22	0.36	0.14	0.03	-13.8	-0.7	19.1	6.9	0.7	0.2	-7.42	-0.28	0.30	1.15	0.02	0.00
	15	-0.46	-0.12	0.32	0.46	0.20	0.04	-16.9	-0.8	22.3	7.9	0.7	0.3	-7.46	-0.28	0.30	1.16	0.02	0.00
	20	-0.71	-0.16	0.54	0.56	0.25	0.06	-19.8	-0.9	25.3	8.9	0.8	0.3	-7.48	-0.29	0.30	1.16	0.02	0.00
20	5	-0.00	-0.05	0.71	0.33	0.05	0.02	-9.9	-0.4	16.0	6.4	0.6	0.2	-5.97	-0.27	0.38	1.15	0.02	-0.00
	10	-0.14	-0.09	0.71	0.43	0.10	0.03	-13.4	-0.7	20.2	7.9	0.8	0.3	-5.99	-0.26	0.38	1.15	0.02	-0.00
	15	-0.36	-0.12	0.82	0.55	0.16	0.04	-17.0	-0.9	24.4	9.3	1.6	0.4	-5.98	-0.27	0.38	1.16	0.02	0.00
	20	-0.65	-0.15	1.08	0.70	0.23	0.06	-21.1	-1.1	29.0	10.9	1.1	0.5	-5.98	-0.27	0.37	1.16	0.02	0.00
21	5	-0.01	-0.05	0.62	0.36	0.05	0.02	-8.1	-0.4	13.7	6.0	0.6	0.3	-5.49	-0.24	0.38	1.14	0.02	-0.00
	10	-0.11	-0.08	0.58	0.45	0.10	0.03	-10.4	-0.8	16.9	7.2	0.9	0.4	-5.52	-0.24	0.38	1.15	0.03	0.00
	15	-0.28	-0.11	0.64	0.56	0.16	0.04	-12.6	-1.2	19.8	8.2	1.3	0.5	-5.48	-0.24	0.37	1.15	0.03	0.00
	20	-0.49	-0.15	0.80	0.69	0.22	0.06	-15.2	-1.5	22.8	9.3	1.5	0.7	-5.45	-0.24	0.37	1.16	0.03	0.00
22	5	0.03	-0.06	0.78	0.13	0.07	0.02	-9.0	-0.4	16.5	3.5	0.6	0.1	-5.17	-0.35	0.34	1.16	0.03	-0.00
	10	-0.09	-0.09	0.80	0.18	0.13	0.03	-10.6	-0.5	18.7	3.9	0.7	0.2	-5.16	-0.35	0.33	1.16	0.03	-0.00
	15	-0.28	-0.12	0.87	0.25	0.19	0.03	-12.0	-0.7	20.3	4.2	0.8	0.2	-5.20	-0.35	0.33	1.16	0.03	-0.00
	20	-0.47	-0.14	1.02	0.31	0.24	0.04	-13.5	-0.8	21.8	4.5	0.9	0.2	-5.25	-0.36	0.33	1.16	0.03	-0.00
23	5	0.05	-0.05	0.46	0.06	0.05	0.02	-8.6	-0.4	15.4	3.2	0.5	0.1	-3.39	-0.40	0.21	1.16	0.02	-0.00
	10	-0.00	-0.08	0.47	0.08	0.09	0.02	-10.7	-0.5	17.4	3.6	0.6	0.1	-3.35	-0.41	0.21	1.16	0.02	-0.00
	15	-0.07	-0.11	0.48	0.10	0.14	0.03	-12.4	-0.5	18.9	3.8	0.7	0.1	-3.35	-0.42	0.20	1.16	0.02	-0.00
	20	-0.15	-0.13	0.56	0.12	0.18	0.04	-13.9	-0.5	20.2	4.1	0.7	0.1	-3.37	-0.43	0.20	1.16	0.02	-0.00
24	5	0.03	-0.07	0.81	0.12	0.06	0.02	-10.0	-0.5	17.0	4.1	0.7	0.2	-4.18	-0.52	0.28	1.16	0.03	-0.00
	10	-0.07	-0.11	0.84	0.16	0.12	0.03	-12.8	-0.7	19.9	4.7	0.9	0.2	-4.09	-0.54	0.27	1.16	0.03	-0.00
	15	-0.24	-0.15	0.86	0.22	0.20	0.04	-15.2	-0.8	22.1	5.1	1.0	0.2	-4.10	-0.55	0.26	1.16	0.03	-0.00
	20	-0.44	-0.18	1.05	0.28	0.26	0.05	-17.2	-1.0	24.0	5.5	1.1	0.3	-4.14	-0.56	0.26	1.17	0.03	-0.00
25	5	0.06	-0.07	0.49	0.24	0.07	0.02	-9.3	-0.4	14.1	4.6	0.6	0.2	-6.32	-0.47	0.32	1.15	0.03	-0.00
	10	-0.03	-0.10	0.47	0.30	0.12	0.03	-11.3	-0.7	16.6	5.3	0.8	0.3	-6.37	-0.47	0.31	1.15	0.03	-0.00
	15	-0.18	-0.14	0.48	0.37	0.18	0.04	-13.1	-1.0	18.8	5.9	1.1	0.4	-6.41	-0.48	0.31	1.16	0.03	0.00
	20	-0.38	-0.17	0.58	0.46	0.25	0.05	-14.8	-1.2	20.8	6.4	1.3	0.4	-6.46	-0.48	0.31	1.16	0.03	0.00
26	5	-0.02	-0.06	0.91	0.43	0.02	0.01	-6.6	-0.6	10.7	4.7	0.8	0.3	-8.08	-0.43	0.47	1.14	0.04	0.00
	10	-0.10	-0.09	0.87	0.52	0.08	0.02	-8.1	-1.0	12.1	5.3	1.3	0.5	-8.08	-0.44	0.46	1.14	0.04	0.00
	15	-0.22	-0.13	0.83	0.62	0.14	0.03	-8.8	-1.5	13.0	5.5	1.8	0.8	-8.09	-0.46	0.46	1.15	0.04	0.00
	20	-0.39	-0.17	0.86	0.74	0.22	0.05	-9.1	-2.1	13.6	5.6	2.3	1.0	-8.14	-0.46	0.45	1.15	0.04	0.00
27	5	-0.06	-0.07	1.45	0.87	-0.01	-0.01	-6.9	-0.8	11.1	5.8	1.2	0.6	-7.00	-0.62	0.60	1.14	0.04	0.00
	10	-0.20	-0.10	1.56	1.12	0.04	-0.00	-7.8	-1.6	12.1	6.2	2.1	1.0	-6.79	-0.65	0.59	1.14	0.04	0.00
	15	-0.37	-0.15	1.69	1.37	0.11	0.01	-8.3	-2.5	12.3	6.2	3.2	1.6	-6.48	-0.69	0.58	1.15	0.04	0.00
	20	-0.54	-0.22	1.84	1.58	0.20	0.04	-8.0	-3.6	11.4	5.5	4.6	2.3	-6.39	-0.72	0.58	1.15	0.04	0.00

TABLE A(III)-12. FALL PLOW CORN, FALL FERTILIZATION (C SOIL ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.30	-0.04	7.68	0.65	-0.17	0.03	-12.1	-0.3	49.4	12.0	1.1	0.2	-0.27	-0.15	0.05	1.17	-0.00	-0.00
	10	-1.17	-0.06	10.50	1.29	-0.19	0.04	-22.6	-0.6	70.1	16.8	1.8	0.4	-0.27	-0.15	0.05	1.18	-0.00	-0.00
	15	-2.49	-0.10	13.89	2.07	-0.16	0.06	-35.2	-1.0	99.7	23.9	3.3	0.7	-0.30	-0.14	0.05	1.18	-0.00	-0.00
	20	-4.33	-0.13	18.29	3.12	-0.11	0.07	-54.0	-2.2	153.3	36.8	7.7	1.6	-0.34	-0.14	0.06	1.18	0.00	-0.00
2	5	-0.12	-0.05	7.22	0.26	-0.16	0.04	-10.1	-0.5	39.7	8.3	1.5	0.3	-0.20	-0.20	0.06	1.18	-0.00	-0.00
	10	-0.54	-0.08	8.63	0.54	-0.14	0.05	-17.1	-1.0	53.2	11.1	2.7	0.5	-0.21	-0.20	0.06	1.18	-0.00	-0.00
	15	-1.16	-0.12	10.39	0.89	-0.10	0.07	-25.4	-1.3	69.5	14.5	4.2	0.7	-0.21	-0.19	0.06	1.18	-0.00	-0.00
	20	-2.03	-0.15	12.22	1.30	-0.04	0.08	-31.9	-2.0	86.8	18.1	6.6	1.2	-0.23	-0.19	0.06	1.18	0.00	-0.00
3	5	0.03	-0.03	4.36	0.08	-0.10	0.02	-4.0	-0.2	20.2	2.8	0.9	0.1	-0.41	-0.39	0.06	1.17	-0.00	-0.00
	10	0.01	-0.05	4.95	0.10	-0.11	0.02	-5.7	-0.4	21.6	3.3	1.2	0.2	-0.36	-0.40	0.06	1.17	-0.00	-0.00
	15	-0.03	-0.07	5.42	0.13	-0.12	0.03	-7.2	-0.6	22.2	3.7	1.4	0.2	-0.35	-0.41	0.06	1.17	-0.00	-0.00
	20	-0.10	-0.09	5.84	0.17	-0.11	0.04	-8.9	-0.7	22.9	4.0	1.7	0.2	-0.33	-0.42	0.06	1.17	-0.00	-0.00
4	5	0.02	-0.04	6.09	0.24	-0.21	0.03	-5.4	-0.3	24.9	5.3	1.3	0.3	-0.51	-0.47	0.08	1.17	-0.00	-0.00
	10	-0.12	-0.07	7.63	0.40	-0.27	0.04	-8.6	-0.8	28.5	6.7	2.1	0.5	-0.45	-0.48	0.08	1.17	-0.00	-0.00
	15	-0.36	-0.10	9.07	0.59	-0.31	0.05	-12.9	-1.4	31.6	8.2	3.2	0.7	-0.44	-0.49	0.08	1.17	-0.00	-0.00
	20	-0.77	-0.14	10.47	0.84	-0.32	0.07	-16.3	-2.6	34.6	9.2	5.3	1.1	-0.42	-0.50	0.08	1.18	-0.00	-0.00
5	5	0.09	-0.03	4.71	0.13	-0.13	0.02	-4.1	-0.3	21.5	4.2	1.0	0.2	-1.27	-0.60	0.12	1.17	-0.00	-0.00
	10	0.04	-0.06	5.54	0.20	-0.15	0.03	-6.4	-0.5	24.1	5.1	1.4	0.3	-1.24	-0.61	0.12	1.17	-0.00	-0.00
	15	-0.04	-0.08	6.32	0.28	-0.17	0.05	-9.1	-1.0	25.3	6.0	2.0	0.5	-1.21	-0.63	0.12	1.17	-0.00	-0.00
	20	-0.17	-0.11	7.04	0.37	-0.18	0.06	-12.4	-1.5	26.1	6.9	3.0	0.6	-1.23	-0.64	0.12	1.17	-0.00	-0.00
6	5	-0.29	-0.05	10.54	0.78	-0.52	0.01	-13.8	-0.6	44.8	11.5	1.8	0.5	-0.26	-0.59	0.07	1.18	-0.00	-0.00
	10	-1.30	-0.07	14.65	1.56	-0.67	0.01	-29.9	-1.8	64.5	18.0	3.8	0.9	-0.03	-0.60	0.07	1.18	-0.00	-0.00
	15	-3.41	-0.08	18.94	2.70	-0.75	0.01	-53.6	-4.2	95.4	26.3	7.3	1.8	0.01	-0.59	0.07	1.18	-0.00	-0.00
	20	-6.66	-0.10	24.32	4.19	-0.77	0.00	-84.9	-9.5	132.5	36.6	15.0	3.6	0.03	-0.58	0.07	1.18	-0.00	-0.00
7	5	-0.13	-0.05	8.56	0.64	-0.44	0.01	-7.8	-0.5	26.1	7.8	1.4	0.4	-1.42	-0.59	0.12	1.17	-0.00	-0.00
	10	-0.57	-0.07	11.10	1.10	-0.56	0.02	-14.1	-1.4	32.4	10.9	2.9	0.9	-1.31	-0.61	0.12	1.17	-0.00	-0.00
	15	-1.46	-0.11	13.67	1.74	-0.64	0.03	-22.4	-2.8	41.4	14.2	5.2	1.5	-1.25	-0.62	0.12	1.18	-0.00	-0.00
	20	-2.75	-0.16	16.32	2.50	-0.66	0.04	-30.9	-6.4	50.9	17.3	10.0	2.8	-1.27	-0.63	0.12	1.18	-0.01	-0.00
8	5	0.03	-0.03	4.13	0.21	-0.14	0.02	-4.0	-0.2	17.4	4.0	0.9	0.2	-2.64	-0.57	0.14	1.16	-0.00	-0.00
	10	-0.03	-0.05	4.88	0.28	-0.17	0.03	-5.5	-0.4	19.2	4.8	1.3	0.3	-2.61	-0.58	0.14	1.17	-0.00	-0.00
	15	-0.12	-0.07	5.52	0.37	-0.18	0.04	-7.3	-0.8	20.4	5.6	1.7	0.4	-2.58	-0.60	0.14	1.17	-0.00	-0.00
	20	-0.25	-0.10	6.19	0.48	-0.20	0.05	-9.5	-1.2	20.7	6.3	2.3	0.6	-2.57	-0.61	0.14	1.17	-0.00	-0.00
9	5	-0.63	-0.06	10.55	1.49	-0.57	-0.02	-18.5	-1.3	41.1	14.5	2.4	0.9	-14.94	-0.29	0.38	1.16	-0.02	0.00
	10	-2.05	-0.07	13.69	2.49	-0.68	-0.03	-41.1	-3.7	58.3	23.6	4.8	1.9	-15.43	-0.23	0.39	1.17	-0.02	0.00
	15	-5.49	-0.10	17.93	4.26	-0.75	-0.04	-63.5	-7.7	77.0	30.9	9.7	3.5	-15.99	-0.22	0.40	1.17	-0.02	0.00
	20	-10.60	-0.17	23.35	6.47	-0.65	-0.01	-80.2	-9.0	91.7	36.8	11.5	4.1	-16.64	-0.20	0.42	1.17	-0.02	0.00

TABLE A(III)-12 (CONT)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.36	-0.04	5.88	1.07	-0.24	-0.00	-10.9	-0.6	30.0	11.6	1.5	0.6	-15.08	-0.12	0.43	1.16	-0.02	0.00
	10	-0.89	-0.07	7.97	1.64	-0.30	0.00	-22.4	-1.8	38.1	17.4	2.5	1.2	-15.42	-0.07	0.43	1.16	-0.02	0.00
	15	-2.01	-0.12	9.54	2.41	-0.30	0.02	-37.2	-4.0	48.6	23.5	5.1	2.2	-15.69	-0.04	0.43	1.17	-0.02	0.00
	20	-4.07	-0.22	11.40	3.51	-0.21	0.07	-54.2	-9.2	63.2	30.2	11.0	4.5	-16.10	-0.01	0.44	1.17	-0.02	0.00
11	5	-0.15	-0.03	3.61	0.74	-0.11	0.01	-7.2	-0.3	20.5	9.0	0.8	0.3	-10.35	-0.30	0.39	1.15	-0.01	0.00
	10	-0.33	-0.05	4.46	0.98	-0.13	0.02	-12.7	-0.7	25.8	12.5	1.2	0.6	-10.35	-0.27	0.39	1.16	-0.01	0.00
	15	-0.68	-0.08	5.41	1.32	-0.14	0.03	-20.2	-1.2	30.9	16.4	1.8	0.9	-10.30	-0.27	0.39	1.16	-0.01	0.00
	20	-1.32	-0.14	6.38	1.80	-0.14	0.06	-30.0	-2.2	38.1	21.1	3.1	1.4	-10.26	-0.28	0.39	1.17	-0.01	0.00
12	5	-0.02	-0.03	3.43	0.27	-0.13	0.02	-4.0	-0.2	14.4	4.6	0.8	0.2	-3.83	-0.37	0.20	1.16	-0.01	-0.00
	10	-0.08	-0.04	3.97	0.35	-0.15	0.03	-5.3	-0.5	16.1	5.4	1.1	0.4	-3.87	-0.37	0.20	1.16	-0.01	-0.00
	15	-0.17	-0.07	4.49	0.45	-0.16	0.04	-7.1	-0.7	17.1	6.2	1.6	0.5	-3.89	-0.37	0.20	1.16	-0.01	-0.00
	20	-0.31	-0.09	5.01	0.57	-0.17	0.05	-9.0	-1.1	18.4	7.0	2.1	0.6	-3.90	-0.38	0.20	1.16	-0.01	0.00
13	5	-0.04	-0.02	1.96	0.35	-0.02	0.02	-4.6	-0.2	14.3	5.8	0.5	0.2	-7.46	-0.18	0.39	1.14	-0.01	0.00
	10	-0.10	-0.04	2.32	0.44	-0.02	0.03	-6.5	-0.3	16.9	7.3	0.7	0.3	-7.50	-0.17	0.39	1.15	-0.01	0.00
	15	-0.20	-0.05	2.68	0.55	-0.02	0.04	-8.9	-0.5	19.2	8.7	0.8	0.4	-7.50	-0.17	0.39	1.15	-0.01	0.00
	20	-0.33	-0.08	3.03	0.68	-0.02	0.05	-11.9	-0.6	21.6	10.3	1.1	0.4	-7.50	-0.17	0.39	1.15	-0.01	0.00
14	5	-0.03	-0.02	1.80	0.36	-0.01	0.02	-5.0	-0.2	15.1	6.4	0.5	0.2	-7.66	-0.21	0.38	1.14	-0.01	0.00
	10	-0.10	-0.04	2.22	0.46	-0.02	0.03	-7.5	-0.3	18.2	8.1	0.7	0.3	-7.68	-0.21	0.38	1.15	-0.01	0.00
	15	-0.21	-0.06	2.61	0.58	-0.01	0.04	-10.4	-0.5	20.8	9.8	0.8	0.4	-7.66	-0.21	0.38	1.15	-0.01	0.00
	20	-0.36	-0.08	2.98	0.72	-0.01	0.05	-14.1	-0.6	23.5	11.8	1.0	0.4	-7.63	-0.21	0.38	1.16	-0.01	0.00
15	5	-0.00	-0.03	1.67	0.41	-0.03	0.01	-3.6	-0.3	10.2	5.0	0.7	0.3	-5.44	-0.38	0.31	1.14	-0.01	-0.00
	10	-0.03	-0.04	2.07	0.49	-0.04	0.02	-4.7	-0.5	11.3	5.8	1.0	0.5	-5.41	-0.38	0.31	1.14	-0.01	0.00
	15	-0.07	-0.07	2.43	0.57	-0.04	0.04	-5.7	-0.8	11.4	6.3	1.4	0.7	-5.33	-0.39	0.31	1.15	-0.01	0.00
	20	-0.13	-0.10	2.78	0.66	-0.04	0.05	-6.7	-1.3	11.1	6.7	2.0	0.9	-5.27	-0.41	0.31	1.15	-0.01	0.00
16	5	0.04	-0.02	3.78	0.18	-0.06	0.02	-3.9	-0.2	21.3	4.4	0.7	0.1	-3.43	-0.39	0.19	1.16	-0.00	-0.00
	10	-0.00	-0.04	4.28	0.23	-0.07	0.03	-6.1	-0.3	24.2	5.4	0.8	0.2	-3.42	-0.40	0.19	1.17	-0.00	-0.00
	15	-0.09	-0.06	4.76	0.30	-0.07	0.04	-8.9	-0.4	26.6	6.4	1.0	0.2	-3.45	-0.41	0.20	1.17	-0.00	-0.00
	20	-0.20	-0.08	5.23	0.38	-0.07	0.05	-12.3	-0.6	27.9	7.5	1.4	0.3	-3.49	-0.42	0.20	1.17	-0.00	-0.00
17	5	0.04	-0.02	3.51	0.15	-0.06	0.02	-3.0	-0.1	18.1	3.5	0.7	0.1	-3.58	-0.56	0.18	1.16	-0.00	-0.00
	10	0.02	-0.04	4.00	0.19	-0.07	0.03	-4.5	-0.3	20.1	4.2	0.9	0.2	-3.49	-0.58	0.19	1.16	-0.00	-0.00
	15	-0.02	-0.06	4.40	0.24	-0.07	0.04	-6.3	-0.5	21.7	4.9	1.1	0.3	-3.52	-0.59	0.19	1.17	-0.00	-0.00
	20	-0.09	-0.08	4.81	0.30	-0.07	0.05	-8.6	-0.7	22.9	5.6	1.4	0.3	-3.55	-0.61	0.19	1.17	-0.00	-0.00
18	5	-0.05	-0.02	2.13	0.22	-0.01	0.01	-3.1	-0.1	16.3	3.9	0.4	0.1	-8.58	-0.16	0.35	1.15	-0.01	0.00
	10	-0.10	-0.03	2.52	0.28	-0.02	0.02	-4.4	-0.2	18.2	4.6	0.6	0.1	-8.58	-0.16	0.35	1.15	-0.01	0.00
	15	-0.17	-0.04	2.85	0.34	-0.02	0.03	-5.8	-0.2	19.9	5.3	0.7	0.2	-8.62	-0.16	0.35	1.16	-0.01	0.00
	20	-0.27	-0.05	3.18	0.41	-0.02	0.03	-7.8	-0.4	21.4	6.1	0.8	0.2	-8.65	-0.16	0.35	1.16	-0.01	0.00

TABLE A(III)-12 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.03	-0.03	2.60	0.26	-0.04	0.02	-4.4	-0.2	15.1	5.0	0.5	0.2	-7.37	-0.28	0.29	1.15	-0.01	-0.00
	10	-0.09	-0.04	2.87	0.33	-0.04	0.03	-6.1	-0.3	17.2	6.0	0.7	0.2	-7.42	-0.28	0.29	1.15	-0.01	0.00
	15	-0.17	-0.06	3.10	0.40	-0.03	0.04	-8.1	-0.4	19.1	6.9	0.7	0.3	-7.46	-0.28	0.29	1.16	-0.01	0.00
	20	-0.27	-0.08	3.34	0.48	-0.03	0.05	-10.5	-0.6	20.6	8.0	0.9	0.3	-7.48	-0.29	0.29	1.16	-0.01	0.00
20	5	-0.01	-0.03	2.63	0.33	-0.06	0.02	-4.9	-0.2	14.6	5.8	0.5	0.2	-5.97	-0.27	0.27	1.15	-0.01	-0.00
	10	-0.07	-0.04	2.99	0.41	-0.07	0.03	-7.0	-0.4	17.1	7.2	0.8	0.3	-5.99	-0.26	0.27	1.15	-0.01	-0.00
	15	-0.17	-0.06	3.31	0.52	-0.07	0.04	-9.7	-0.6	19.1	8.6	1.0	0.4	-5.98	-0.27	0.27	1.16	-0.01	0.00
	20	-0.33	-0.09	3.64	0.66	-0.06	0.05	-13.0	-0.7	22.0	10.3	1.3	0.5	-5.98	-0.27	0.27	1.16	-0.01	0.00
21	5	-0.01	-0.03	2.36	0.36	-0.06	0.02	-4.3	-0.2	12.2	5.5	0.6	0.2	-5.49	-0.24	0.26	1.14	-0.01	-0.00
	10	-0.06	-0.04	2.67	0.44	-0.07	0.03	-6.0	-0.4	13.9	6.7	0.8	0.4	-5.52	-0.24	0.26	1.15	-0.01	0.00
	15	-0.15	-0.06	2.95	0.54	-0.06	0.04	-8.0	-0.7	15.3	7.8	1.2	0.5	-5.48	-0.24	0.26	1.15	-0.01	0.00
	20	-0.28	-0.09	3.24	0.65	-0.06	0.05	-10.2	-1.0	16.8	8.9	1.7	0.7	-5.45	-0.24	0.25	1.16	-0.01	0.00
22	5	0.04	-0.02	3.89	0.13	-0.12	0.01	-2.1	-0.1	15.9	2.5	0.6	0.1	-5.17	-0.35	0.22	1.16	-0.01	-0.00
	10	0.02	-0.03	4.28	0.16	-0.13	0.02	-3.1	-0.2	17.1	2.9	0.8	0.1	-5.16	-0.35	0.22	1.16	-0.01	-0.00
	15	-0.02	-0.04	4.64	0.19	-0.13	0.02	-4.2	-0.3	17.7	3.2	0.9	0.1	-5.20	-0.35	0.22	1.16	-0.01	-0.00
	20	-0.07	-0.05	4.99	0.23	-0.14	0.03	-5.5	-0.4	18.2	3.6	0.9	0.2	-5.25	-0.36	0.23	1.16	-0.01	-0.00
23	5	0.04	-0.01	2.29	0.06	0.00	0.01	-2.4	-0.1	15.1	2.3	0.5	0.1	-3.39	-0.40	0.17	1.16	0.00	-0.00
	10	0.03	-0.02	2.45	0.07	0.00	0.02	-3.3	-0.2	16.1	2.6	0.6	0.1	-3.35	-0.41	0.17	1.16	0.00	-0.00
	15	0.02	-0.04	2.60	0.08	0.00	0.02	-4.3	-0.2	16.6	2.9	0.6	0.1	-3.35	-0.42	0.17	1.16	0.00	-0.00
	20	0.00	-0.05	2.74	0.09	0.01	0.03	-5.4	-0.3	16.9	3.2	0.7	0.1	-3.37	-0.43	0.17	1.16	0.00	-0.00
24	5	0.03	-0.02	3.51	0.12	-0.07	0.01	-3.0	-0.1	17.2	3.0	0.7	0.1	-4.18	-0.52	0.19	1.16	-0.00	-0.00
	10	0.01	-0.04	3.89	0.14	-0.07	0.02	-4.3	-0.3	18.9	3.6	0.9	0.2	-4.09	-0.54	0.19	1.16	-0.00	-0.00
	15	-0.03	-0.05	4.22	0.17	-0.07	0.03	-5.8	-0.4	19.8	4.0	1.0	0.2	-4.10	-0.55	0.19	1.16	-0.00	-0.00
	20	-0.09	-0.07	4.56	0.22	-0.07	0.04	-7.7	-0.6	20.2	4.5	1.2	0.3	-4.14	-0.56	0.19	1.17	-0.00	-0.00
25	5	0.04	-0.02	3.01	0.24	-0.09	0.01	-2.8	-0.1	13.6	3.7	0.6	0.2	-6.32	-0.47	0.24	1.15	-0.01	-0.00
	10	0.01	-0.04	3.38	0.28	-0.10	0.02	-4.2	-0.3	15.0	4.4	0.9	0.2	-6.37	-0.47	0.24	1.15	-0.01	-0.00
	15	-0.03	-0.05	3.72	0.34	-0.11	0.03	-5.7	-0.5	16.0	5.0	1.1	0.3	-6.41	-0.48	0.24	1.16	-0.01	0.00
	20	-0.10	-0.07	4.05	0.40	-0.11	0.04	-7.4	-0.8	16.8	5.6	1.3	0.4	-6.46	-0.48	0.24	1.16	-0.01	0.00
26	5	-0.03	-0.03	3.04	0.43	-0.14	0.01	-3.3	-0.3	10.2	4.2	0.8	0.3	-8.08	-0.43	0.30	1.14	-0.01	0.00
	10	-0.07	-0.05	3.52	0.51	-0.17	0.02	-4.2	-0.6	10.9	4.7	1.2	0.5	-8.08	-0.44	0.30	1.14	-0.02	0.00
	15	-0.13	-0.07	3.95	0.60	-0.18	0.03	-5.1	-1.0	10.9	5.0	1.6	0.7	-8.09	-0.46	0.30	1.15	-0.02	0.00
	20	-0.21	-0.10	4.36	0.69	-0.18	0.04	-6.2	-1.5	10.5	5.3	2.2	1.0	-8.14	-0.46	0.30	1.15	-0.02	0.00
27	5	-0.05	-0.04	2.72	0.87	-0.11	-0.01	-3.7	-0.4	10.9	5.4	1.1	0.6	-7.00	-0.62	0.36	1.14	-0.01	0.00
	10	-0.13	-0.06	3.60	1.10	-0.15	-0.01	-4.8	-1.1	10.9	5.9	1.8	1.0	-6.79	-0.65	0.35	1.14	-0.01	0.00
	15	-0.23	-0.11	4.48	1.34	-0.19	0.01	-5.8	-2.0	9.9	6.0	2.9	1.5	-6.48	-0.69	0.34	1.15	-0.01	0.00
	20	-0.37	-0.17	5.14	1.55	-0.17	0.03	-5.4	-3.4	8.0	5.3	4.5	2.3	-6.39	-0.72	0.34	1.15	-0.01	0.00

TABLE A(III)-13. FALL PLOW CORN (D SOIL ONLY)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	0.69	18.94	-0.63	29.94	10	5	1.45	16.06	-1.38	38.67	19	5	1.13	32.19	-1.10	35.97
	10	0.62	18.73	-0.50	18.50		10	1.41	15.67	-1.14	24.67		10	1.13	31.97	-1.04	29.01
	15	0.57	18.16	-0.43	10.71		15	1.33	14.99	-1.01	16.52		15	1.10	31.68	-0.97	24.27
	20	0.51	17.50	-0.29	4.34		20	1.28	14.25	-0.81	10.40		20	1.08	31.27	-0.94	20.68
2	5	1.09	20.70	-1.05	33.40	11	5	1.31	24.19	-1.26	38.79	20	5	1.16	32.53	-1.13	36.20
	10	1.02	20.62	-0.93	23.26		10	1.25	23.93	-1.04	26.49		10	1.17	32.28	-1.06	27.75
	15	0.96	20.34	-0.82	16.26		15	1.23	23.32	-0.91	19.01		15	1.16	31.95	-0.98	22.20
	20	0.88	20.05	-0.73	11.47		20	1.20	22.65	-0.82	13.35		20	1.12	31.56	-0.88	17.72
3	5	1.50	25.10	-1.49	43.00	12	5	1.70	22.23	-1.67	44.90	21	5	1.37	32.29	-1.35	37.57
	10	1.54	24.76	-1.53	37.59		10	1.76	21.88	-1.68	36.70		10	1.41	31.96	-1.32	29.46
	15	1.54	24.52	-1.53	34.58		15	1.79	21.50	-1.64	31.26		15	1.40	31.51	-1.26	24.16
	20	1.53	24.22	-1.53	32.21		20	1.79	21.00	-1.58	26.99		20	1.38	31.11	-1.22	20.21
4	5	1.60	17.73	-1.57	41.66	13	5	1.23	35.54	-1.19	36.18	22	5	1.31	27.75	-1.30	42.62
	10	1.63	17.31	-1.53	32.40		10	1.22	35.44	-1.08	27.63		10	1.33	27.49	-1.31	37.19
	15	1.60	16.97	-1.44	26.03		15	1.20	35.14	-0.95	21.99		15	1.32	27.25	-1.32	34.01
	20	1.56	16.53	-1.43	21.46		20	1.18	34.77	-0.85	17.60		20	1.33	26.93	-1.32	31.54
5	5	1.54	20.71	-1.52	41.89	14	5	1.06	36.62	-1.02	33.41	23	5	1.16	39.62	-1.15	38.00
	10	1.57	20.48	-1.49	34.24		10	1.07	36.37	-0.90	24.68		10	1.18	39.41	-1.15	33.71
	15	1.56	20.11	-1.49	29.33		15	1.05	36.01	-0.80	19.14		15	1.20	39.18	-1.19	31.08
	20	1.56	19.73	-1.48	25.53		20	1.01	35.57	-0.70	14.88		20	1.20	38.93	-1.19	29.00
6	5	1.12	11.09	-1.03	33.05	15	5	1.78	28.55	-1.76	40.82	24	5	1.36	27.81	-1.35	41.39
	10	1.06	10.69	-0.81	19.49		10	1.82	28.19	-1.75	33.13		10	1.37	27.55	-1.33	35.21
	15	0.98	10.42	-0.65	11.46		15	1.84	27.73	-1.76	28.74		15	1.37	27.25	-1.34	31.56
	20	0.90	10.03	-0.47	6.16		20	1.84	27.27	-1.77	25.59		20	1.35	26.95	-1.34	28.80
7	5	1.60	11.01	-1.53	40.90	16	5	1.12	26.96	-1.09	38.91	25	5	1.52	28.13	-1.50	43.08
	10	1.64	10.53	-1.41	27.98		10	1.10	26.73	-1.02	31.66		10	1.53	27.93	-1.48	35.77
	15	1.61	10.01	-1.21	19.64		15	1.08	26.43	-0.97	26.54		15	1.55	27.54	-1.50	31.00
	20	1.57	9.55	-1.04	13.44		20	1.07	26.07	-0.98	23.01		20	1.55	27.14	-1.49	27.37
8	5	1.62	21.26	-1.58	43.06	17	5	1.34	25.89	-1.32	41.27	26	5	2.23	18.57	-2.21	49.15
	10	1.68	20.89	-1.59	35.23		10	1.36	25.62	-1.30	34.39		10	2.30	18.08	-2.25	41.10
	15	1.70	20.50	-1.56	30.09		15	1.34	25.31	-1.28	29.75		15	2.34	17.50	-2.30	36.81
	20	1.70	20.07	-1.56	26.32		20	1.34	24.94	-1.27	25.94		20	2.36	17.07	-2.32	33.71
9	5	1.49	8.41	-1.37	35.59	18	5	0.95	36.65	-0.94	35.50	27	5	2.58	11.96	-2.55	50.38
	10	1.39	7.85	-1.03	20.58		10	0.94	36.47	-0.90	29.08		10	2.66	11.22	-2.61	41.95
	15	1.33	7.31	-0.91	13.35		15	0.92	36.15	-0.86	24.64		15	2.74	10.38	-2.63	36.96
	20	1.26	6.83	-0.76	8.54		20	0.90	35.69	-0.85	21.22		20	2.79	9.53	-2.66	33.51

TABLE A(LLL)-14. FALL PLOW CORN, SPRING FERTILIZATION (D SOIL ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-1.06	-0.05	2.25	0.84	0.20	0.03	-21.7	-0.5	66.2	14.5	1.5	0.3	-0.33	-0.12	0.14	1.18	0.02	-0.00
	10	-2.46	-0.07	5.56	1.64	0.29	0.04	-30.7	-0.9	94.7	20.8	2.8	0.6	-0.33	-0.12	0.14	1.18	0.02	-0.00
	15	-3.94	-0.10	9.73	2.57	0.43	0.07	-46.6	-2.1	144.7	31.7	6.6	1.5	-0.36	-0.11	0.15	1.18	0.02	-0.00
	20	-5.84	-0.14	15.43	3.81	0.56	0.10	-82.4	-1.9	260.2	56.9	7.6	1.8	-0.39	-0.11	0.15	1.18	0.02	-0.00
2	5	-0.51	-0.08	1.08	0.36	0.24	0.04	-17.2	-0.7	52.7	9.6	2.1	0.4	-0.29	-0.17	0.09	1.18	0.03	-0.00
	10	-1.27	-0.10	2.55	0.70	0.36	0.05	-22.8	-1.2	71.0	12.9	3.8	0.7	-0.30	-0.17	0.10	1.18	0.03	-0.00
	15	-2.04	-0.12	4.55	1.11	0.48	0.07	-29.9	-2.3	93.7	17.0	7.2	1.4	-0.31	-0.16	0.09	1.18	0.03	-0.00
	20	-2.87	-0.15	7.06	1.57	0.58	0.09	-38.9	-3.2	121.5	22.0	10.3	2.0	-0.33	-0.16	0.10	1.18	0.03	-0.00
3	5	-0.05	-0.08	0.30	0.12	0.16	0.02	-13.0	-0.9	26.1	4.0	1.3	0.2	-0.53	-0.34	0.08	1.17	0.03	-0.00
	10	-0.18	-0.13	0.42	0.16	0.25	0.03	-15.7	-1.2	29.6	4.5	1.8	0.3	-0.48	-0.35	0.07	1.17	0.04	-0.00
	15	-0.34	-0.17	0.62	0.21	0.32	0.04	-17.3	-1.4	31.7	4.8	2.1	0.3	-0.47	-0.36	0.07	1.17	0.04	-0.00
	20	-0.55	-0.21	0.90	0.26	0.40	0.05	-18.7	-1.5	33.5	5.0	2.3	0.4	-0.46	-0.37	0.07	1.18	0.04	-0.00
4	5	-0.16	-0.11	0.35	0.31	0.21	0.03	-17.4	-1.3	31.8	6.9	1.9	0.4	-0.59	-0.42	0.08	1.17	0.04	-0.00
	10	-0.73	-0.16	0.95	0.55	0.32	0.05	-22.7	-2.1	39.2	8.3	3.2	0.7	-0.54	-0.42	0.08	1.18	0.04	-0.00
	15	-1.46	-0.23	1.88	0.81	0.43	0.06	-27.5	-3.0	46.1	9.7	4.8	1.1	-0.53	-0.43	0.07	1.18	0.04	-0.00
	20	-2.39	-0.29	3.12	1.12	0.55	0.08	-29.1	-5.1	48.7	10.1	8.4	1.9	-0.53	-0.44	0.07	1.18	0.04	-0.00
5	5	0.04	-0.10	0.11	0.18	0.17	0.03	-15.5	-1.1	26.4	5.8	1.5	0.3	-1.36	-0.53	0.09	1.17	0.04	-0.00
	10	-0.23	-0.16	0.37	0.29	0.26	0.04	-19.8	-1.7	31.7	6.8	2.2	0.5	-1.34	-0.54	0.09	1.17	0.04	-0.00
	15	-0.58	-0.21	0.78	0.41	0.34	0.06	-23.1	-2.4	35.6	7.6	3.3	0.7	-1.32	-0.55	0.09	1.17	0.04	-0.00
	20	-0.99	-0.27	1.32	0.54	0.43	0.07	-25.7	-3.5	38.5	8.2	4.7	1.0	-1.34	-0.57	0.09	1.17	0.04	-0.00
6	5	-0.79	-0.09	6.08	1.00	-0.06	0.02	-31.4	-1.7	55.2	14.1	2.6	0.6	-0.40	-0.49	0.53	1.18	0.03	-0.00
	10	-3.04	-0.12	8.44	2.00	0.05	0.02	-54.9	-4.3	87.2	21.7	6.1	1.5	-0.24	-0.50	0.51	1.18	0.03	-0.00
	15	-6.70	-0.17	13.13	3.36	0.18	0.03	-85.1	-9.6	128.3	31.6	13.6	3.4	-0.23	-0.48	0.50	1.18	0.03	-0.00
	20	-11.51	-0.25	19.52	5.06	0.33	0.05	-115.0	-14.9	170.3	41.0	22.3	5.7	-0.23	-0.48	0.49	1.18	0.03	-0.00
7	5	-0.33	-0.09	4.23	0.78	-0.05	0.02	-17.5	-1.3	30.9	9.3	2.0	0.6	-1.37	-0.52	0.50	1.17	0.03	-0.00
	10	-1.29	-0.14	4.92	1.35	0.07	0.03	-25.8	-3.3	42.5	12.4	4.6	1.3	-1.28	-0.54	0.49	1.18	0.04	-0.00
	15	-2.86	-0.21	6.64	2.09	0.20	0.04	-35.2	-6.2	54.3	15.6	8.6	2.5	-1.24	-0.55	0.47	1.18	0.04	-0.00
	20	-4.93	-0.32	9.16	2.94	0.40	0.08	-42.2	-11.8	62.0	17.4	17.1	5.0	-1.28	-0.55	0.46	1.18	0.04	-0.00
8	5	0.00	-0.08	0.75	0.25	0.09	0.02	-12.8	-0.8	20.4	5.4	1.2	0.3	-2.55	-0.51	0.21	1.17	0.04	-0.00
	10	-0.22	-0.12	0.78	0.38	0.18	0.04	-15.6	-1.5	24.3	6.3	1.9	0.5	-2.53	-0.52	0.21	1.17	0.04	-0.00
	15	-0.51	-0.18	0.96	0.51	0.28	0.05	-18.1	-2.1	27.6	7.1	2.7	0.7	-2.51	-0.53	0.20	1.17	0.04	-0.00
	20	-0.87	-0.23	1.29	0.65	0.37	0.07	-20.1	-3.0	30.1	7.5	3.7	1.0	-2.50	-0.55	0.19	1.17	0.04	-0.00
9	5	-1.26	-0.12	2.12	1.87	0.16	-0.02	-36.4	-2.8	47.2	17.3	3.2	1.2	-14.01	-0.31	0.60	1.17	0.03	0.00
	10	-4.20	-0.13	4.01	3.32	0.27	-0.03	-61.8	-6.6	76.0	26.6	7.3	2.7	-14.30	-0.27	0.61	1.17	0.03	0.00
	15	-9.22	-0.19	8.82	5.46	0.41	-0.02	-75.9	-11.7	91.9	31.5	13.4	4.7	-14.72	-0.26	0.62	1.17	0.03	0.00
	20	-15.66	-0.41	15.66	8.01	0.68	0.06	-141.7	4.2	165.1	55.6	-3.6	-1.2	-15.35	-0.25	0.64	1.18	0.03	0.00

TABLE A(III)-14 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.62	-0.09	1.49	1.30	0.12	0.00	-25.6	-1.7	33.1	14.3	1.9	0.8	-14.24	-0.14	0.64	1.16	0.02	0.00
	10	-1.90	-0.14	2.01	2.11	0.22	0.01	-40.5	-4.0	50.0	20.6	4.3	1.8	-14.54	-0.10	0.65	1.17	0.02	0.00
	15	-4.12	-0.22	3.50	3.21	0.38	0.04	-54.8	-9.1	66.5	26.3	9.7	4.0	-14.76	-0.07	0.66	1.17	0.02	0.00
	20	-7.07	-0.43	6.19	4.58	0.66	0.13	-69.2	-15.1	83.3	31.7	16.4	6.7	-15.09	-0.05	0.67	1.17	0.02	0.00
11	5	-0.26	-0.08	0.89	0.89	0.08	0.02	-17.9	-1.0	23.9	11.3	1.1	0.5	-10.12	-0.26	0.52	1.16	0.02	0.00
	10	-0.76	-0.12	1.07	1.26	0.15	0.03	-28.0	-2.0	34.9	15.8	2.1	1.0	-10.14	-0.24	0.52	1.16	0.02	0.00
	15	-1.61	-0.18	1.62	1.74	0.25	0.05	-38.9	-3.6	47.2	20.6	3.7	1.7	-10.10	-0.24	0.52	1.17	0.02	0.00
	20	-2.80	-0.28	2.72	2.37	0.39	0.09	-51.2	-7.0	60.7	25.7	7.1	3.4	-10.05	-0.24	0.52	1.17	0.02	0.00
12	5	-0.05	-0.06	1.66	0.33	0.02	0.02	-9.0	-0.7	16.8	5.5	1.1	0.3	-3.82	-0.32	0.49	1.16	0.03	-0.00
	10	-0.22	-0.09	1.66	0.45	0.09	0.03	-11.3	-1.3	20.2	6.4	1.8	0.5	-3.85	-0.33	0.48	1.16	0.03	-0.00
	15	-0.45	-0.14	1.81	0.58	0.17	0.05	-13.9	-1.9	23.3	7.2	2.5	0.8	-3.87	-0.33	0.48	1.16	0.03	0.00
	20	-0.76	-0.18	2.10	0.73	0.26	0.07	-16.5	-2.5	26.2	8.0	3.3	1.0	-3.89	-0.34	0.48	1.17	0.03	0.00
13	5	-0.07	-0.05	0.45	0.41	0.07	0.02	-10.9	-0.7	17.7	7.3	0.9	0.3	-7.34	-0.17	0.46	1.15	0.02	0.00
	10	-0.24	-0.08	0.48	0.55	0.12	0.03	-15.8	-1.2	23.6	9.3	1.3	0.5	-7.37	-0.16	0.46	1.15	0.02	0.00
	15	-0.49	-0.12	0.67	0.70	0.18	0.05	-20.4	-1.6	29.4	11.3	1.7	0.7	-7.37	-0.15	0.46	1.16	0.02	0.00
	20	-0.82	-0.17	0.98	0.88	0.26	0.07	-25.8	-1.9	35.9	13.5	2.0	0.9	-7.38	-0.16	0.46	1.16	0.02	0.00
14	5	-0.06	-0.05	0.40	0.43	0.06	0.02	-12.7	-0.7	19.0	8.2	0.8	0.3	-7.56	-0.19	0.41	1.15	0.02	0.00
	10	-0.26	-0.09	0.46	0.58	0.12	0.03	-18.6	-1.2	26.0	10.7	1.3	0.5	-7.58	-0.19	0.41	1.15	0.02	0.00
	15	-0.55	-0.14	0.68	0.76	0.19	0.05	-24.3	-1.6	32.9	13.1	1.7	0.7	-7.57	-0.19	0.41	1.16	0.02	0.00
	20	-0.90	-0.19	1.00	0.95	0.27	0.07	-30.9	-2.0	40.8	15.9	2.0	1.0	-7.53	-0.18	0.41	1.16	0.02	0.00
15	5	-0.00	-0.05	0.50	0.49	0.05	0.02	-7.2	-0.8	11.8	5.8	1.0	0.5	-5.44	-0.34	0.39	1.14	0.03	0.00
	10	-0.07	-0.09	0.48	0.59	0.10	0.03	-9.0	-1.4	14.1	6.6	1.7	0.8	-5.41	-0.34	0.39	1.15	0.03	0.00
	15	-0.17	-0.13	0.51	0.70	0.17	0.05	-10.0	-2.1	15.3	6.9	2.5	1.2	-5.35	-0.36	0.39	1.15	0.03	0.00
	20	-0.29	-0.19	0.59	0.81	0.24	0.08	-10.7	-2.9	15.7	6.8	3.5	1.7	-5.29	-0.37	0.38	1.16	0.03	0.00
16	5	0.00	-0.07	1.27	0.22	0.07	0.02	-14.0	-0.7	25.7	6.1	1.0	0.2	-3.41	-0.34	0.34	1.17	0.02	-0.00
	10	-0.22	-0.11	1.41	0.31	0.15	0.04	-19.6	-1.0	31.8	7.5	1.3	0.3	-3.40	-0.34	0.34	1.17	0.02	-0.00
	15	-0.52	-0.16	1.78	0.42	0.23	0.05	-25.0	-1.3	37.6	8.7	1.6	0.4	-3.43	-0.35	0.34	1.17	0.02	-0.00
	20	-0.86	-0.21	2.22	0.53	0.31	0.06	-29.1	-1.6	42.2	9.7	2.1	0.5	-3.46	-0.36	0.33	1.17	0.02	-0.00
17	5	0.03	-0.08	0.93	0.19	0.07	0.02	-12.7	-0.7	20.1	5.2	0.9	0.2	-3.51	-0.49	0.26	1.16	0.03	-0.00
	10	-0.14	-0.13	0.96	0.27	0.15	0.04	-16.1	-1.1	24.2	6.1	1.3	0.3	-3.44	-0.50	0.25	1.17	0.03	-0.00
	15	-0.37	-0.17	1.10	0.35	0.23	0.05	-19.5	-1.4	27.7	6.9	1.7	0.4	-3.47	-0.51	0.25	1.17	0.03	-0.00
	20	-0.66	-0.22	1.39	0.44	0.31	0.07	-22.7	-1.9	31.1	7.7	2.1	0.6	-3.50	-0.53	0.25	1.17	0.03	-0.00
18	5	-0.14	-0.06	0.67	0.28	0.06	0.02	-11.7	-0.5	18.0	5.8	0.6	0.2	-8.38	-0.14	0.40	1.15	0.02	0.00
	10	-0.40	-0.09	0.77	0.39	0.12	0.03	-15.5	-0.8	22.2	6.9	0.8	0.3	-8.39	-0.14	0.40	1.16	0.02	0.00
	15	-0.73	-0.11	0.92	0.52	0.18	0.04	-19.1	-1.0	26.2	7.9	0.9	0.3	-8.43	-0.14	0.40	1.16	0.02	0.00
	20	-1.07	-0.14	1.23	0.64	0.23	0.05	-22.6	-1.2	29.8	8.9	1.1	0.4	-8.46	-0.14	0.40	1.16	0.02	0.00

TABLE A(III)-14 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.08	-0.06	0.30	0.32	0.08	0.02	-12.6	-0.7	18.2	6.7	0.8	0.3	-7.12	-0.25	0.30	1.15	0.02	0.00
	10	-0.31	-0.10	0.34	0.43	0.14	0.04	-16.5	-1.0	22.7	8.1	1.1	0.4	-7.17	-0.25	0.30	1.16	0.02	0.00
	15	-0.60	-0.14	0.51	0.56	0.21	0.05	-20.6	-1.3	27.1	9.4	1.3	0.5	-7.21	-0.25	0.30	1.16	0.02	0.00
	20	-0.90	-0.18	0.78	0.68	0.27	0.06	-24.4	-1.6	31.1	10.7	1.6	0.6	-7.23	-0.26	0.30	1.16	0.02	0.00
20	5	-0.04	-0.05	0.81	0.40	0.05	0.02	-11.8	-0.6	18.4	7.3	0.8	0.3	-5.92	-0.23	0.39	1.15	0.02	-0.00
	10	-0.23	-0.09	0.84	0.53	0.11	0.03	-16.2	-1.2	24.0	9.2	1.3	0.5	-5.94	-0.23	0.38	1.16	0.02	0.00
	15	-0.50	-0.13	1.02	0.68	0.18	0.05	-20.8	-1.7	29.5	11.0	1.8	0.7	-5.94	-0.23	0.38	1.16	0.02	0.00
	20	-0.87	-0.19	1.37	0.87	0.26	0.07	-26.6	-2.2	36.2	13.3	2.2	0.9	-5.93	-0.23	0.38	1.16	0.02	0.00
21	5	-0.03	-0.05	0.71	0.43	0.05	0.02	-9.4	-0.6	15.5	6.7	0.9	0.4	-5.44	-0.22	0.38	1.15	0.02	0.00
	10	-0.18	-0.09	0.69	0.55	0.11	0.03	-12.1	-1.3	19.4	8.1	1.5	0.6	-5.46	-0.21	0.38	1.15	0.02	0.00
	15	-0.39	-0.13	0.78	0.69	0.18	0.05	-14.6	-2.0	22.8	9.3	2.2	0.9	-5.43	-0.22	0.38	1.16	0.02	0.00
	20	-0.65	-0.18	1.00	0.84	0.26	0.07	-17.5	-2.7	26.2	10.3	3.1	1.3	-5.41	-0.22	0.38	1.16	0.02	0.00
22	5	0.00	-0.07	0.93	0.16	0.07	0.02	-10.3	-0.5	18.5	3.9	0.8	0.2	-5.09	-0.30	0.35	1.16	0.02	-0.00
	10	-0.16	-0.10	0.97	0.23	0.13	0.03	-12.3	-0.8	21.2	4.4	1.0	0.2	-5.08	-0.30	0.34	1.16	0.03	-0.00
	15	-0.37	-0.12	1.08	0.30	0.20	0.03	-14.1	-1.0	23.2	4.8	1.2	0.3	-5.13	-0.31	0.34	1.16	0.03	0.00
	20	-0.60	-0.15	1.30	0.37	0.26	0.04	-15.8	-1.1	24.9	5.1	1.3	0.3	-5.17	-0.31	0.34	1.17	0.03	0.00
23	5	0.03	-0.05	0.61	0.08	0.05	0.02	-10.1	-0.5	17.5	3.6	0.8	0.1	-3.42	-0.36	0.23	1.16	0.02	-0.00
	10	-0.04	-0.08	0.63	0.10	0.09	0.02	-12.8	-0.7	20.1	4.1	0.9	0.2	-3.39	-0.37	0.22	1.16	0.02	-0.00
	15	-0.12	-0.12	0.68	0.13	0.15	0.03	-14.8	-0.8	21.9	4.4	1.0	0.2	-3.39	-0.38	0.22	1.16	0.02	-0.00
	20	-0.22	-0.14	0.78	0.15	0.20	0.04	-16.4	-0.8	23.3	4.7	1.0	0.2	-3.41	-0.39	0.22	1.16	0.02	-0.00
24	5	0.01	-0.07	1.00	0.15	0.06	0.02	-11.5	-0.7	19.0	4.6	0.9	0.2	-4.09	-0.45	0.29	1.16	0.03	-0.00
	10	-0.12	-0.12	1.04	0.20	0.13	0.03	-15.0	-1.0	22.5	5.3	1.2	0.3	-4.01	-0.47	0.28	1.17	0.03	-0.00
	15	-0.32	-0.16	1.13	0.27	0.21	0.05	-17.7	-1.3	25.1	5.8	1.5	0.4	-4.03	-0.48	0.28	1.17	0.03	-0.00
	20	-0.55	-0.20	1.36	0.34	0.27	0.06	-19.9	-1.5	27.2	6.3	1.7	0.4	-4.07	-0.49	0.28	1.17	0.03	-0.00
25	5	0.05	-0.07	0.59	0.28	0.07	0.02	-10.6	-0.6	15.8	5.1	0.8	0.3	-6.19	-0.41	0.32	1.15	0.03	-0.00
	10	-0.08	-0.11	0.59	0.36	0.12	0.03	-13.0	-1.0	18.8	5.9	1.2	0.4	-6.24	-0.41	0.32	1.16	0.03	0.00
	15	-0.27	-0.15	0.62	0.45	0.20	0.04	-15.0	-1.5	21.3	6.6	1.7	0.6	-6.28	-0.42	0.32	1.16	0.03	0.00
	20	-0.50	-0.19	0.77	0.55	0.27	0.06	-16.9	-2.1	23.6	7.1	2.3	0.7	-6.33	-0.43	0.32	1.16	0.03	0.00
26	5	-0.03	-0.06	1.06	0.51	0.02	0.01	-7.3	-0.7	11.3	4.9	1.0	0.4	-7.56	-0.42	0.45	1.14	0.03	0.00
	10	-0.14	-0.10	1.03	0.62	0.08	0.02	-8.6	-1.4	12.7	5.5	1.8	0.7	-7.55	-0.43	0.45	1.15	0.04	0.00
	15	-0.30	-0.14	1.00	0.75	0.16	0.04	-8.9	-2.2	13.3	5.5	2.6	1.1	-7.55	-0.44	0.44	1.15	0.04	0.00
	20	-0.49	-0.20	1.04	0.88	0.25	0.06	-8.7	-3.2	13.3	5.4	3.4	1.4	-7.61	-0.45	0.44	1.15	0.04	0.00
27	5	-0.09	-0.07	1.57	1.05	-0.00	-0.01	-7.3	-1.0	11.5	6.0	1.4	0.7	-6.78	-0.59	0.58	1.14	0.03	0.00
	10	-0.27	-0.12	1.72	1.36	0.06	-0.00	-7.9	-2.2	12.1	6.1	2.7	1.3	-6.58	-0.62	0.58	1.15	0.04	0.00
	15	-0.49	-0.19	1.87	1.65	0.15	0.02	-7.9	-3.4	11.5	5.6	4.3	2.0	-6.34	-0.65	0.57	1.15	0.04	0.00
	20	-0.66	-0.28	2.04	1.87	0.26	0.06	-6.4	-5.0	8.6	4.1	6.5	3.1	-6.25	-0.67	0.57	1.16	0.04	0.00

TABLE A(III)-15. FALL PLOW CORN, FALL FERTILIZATION (D SOIL ONLY)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.44	-0.04	8.92	0.79	-0.15	0.03	-15.7	-0.5	56.1	14.1	1.5	0.3	-0.33	-0.12	0.05	1.18	-0.00	-0.00
	10	-1.64	-0.07	12.31	1.59	-0.13	0.04	-29.7	-1.0	84.1	20.7	3.0	0.6	-0.33	-0.12	0.05	1.18	-0.00	-0.00
	15	-3.30	-0.12	16.40	2.53	-0.07	0.07	-46.8	-2.2	127.9	31.6	7.1	1.5	-0.36	-0.11	0.05	1.18	-0.00	-0.00
	20	-5.49	-0.15	21.73	3.78	0.02	0.10	-82.6	-2.0	227.7	56.9	9.0	1.8	-0.39	-0.11	0.05	1.18	0.00	-0.00
2	5	-0.18	-0.06	8.21	0.33	-0.15	0.04	-12.5	-0.7	43.4	9.3	2.1	0.4	-0.29	-0.17	0.06	1.18	-0.00	-0.00
	10	-0.70	-0.10	9.82	0.66	-0.10	0.05	-21.8	-1.4	60.0	12.8	3.9	0.7	-0.30	-0.17	0.06	1.18	-0.00	-0.00
	15	-1.50	-0.14	11.84	1.07	-0.03	0.07	-30.1	-2.4	78.7	17.0	7.3	1.4	-0.31	-0.16	0.06	1.18	-0.00	-0.00
	20	-2.51	-0.16	13.91	1.54	0.04	0.09	-39.0	-3.3	102.6	22.0	10.4	2.0	-0.33	-0.16	0.07	1.18	0.00	-0.00
3	5	0.03	-0.03	5.00	0.10	-0.10	0.02	-5.2	-0.4	21.2	3.2	1.1	0.2	-0.53	-0.34	0.06	1.17	-0.00	-0.00
	10	-0.00	-0.06	5.60	0.13	-0.10	0.03	-7.3	-0.6	22.4	3.8	1.5	0.3	-0.48	-0.35	0.06	1.17	-0.00	-0.00
	15	-0.06	-0.09	6.07	0.17	-0.09	0.04	-9.2	-0.9	23.1	4.2	1.9	0.3	-0.47	-0.36	0.06	1.17	-0.00	-0.00
	20	-0.17	-0.11	6.50	0.22	-0.08	0.04	-10.7	-1.1	24.1	4.5	2.3	0.3	-0.46	-0.37	0.06	1.18	-0.00	-0.00
4	5	0.01	-0.04	7.08	0.28	-0.21	0.03	-6.7	-0.5	25.8	5.9	1.5	0.4	-0.59	-0.42	0.08	1.17	-0.00	-0.00
	10	-0.19	-0.08	8.72	0.48	-0.26	0.04	-11.0	-1.2	29.0	7.5	2.8	0.7	-0.54	-0.42	0.08	1.18	-0.00	-0.00
	15	-0.54	-0.12	10.23	0.72	-0.28	0.06	-15.4	-2.3	32.6	9.0	4.7	1.0	-0.53	-0.43	0.08	1.18	-0.00	-0.00
	20	-1.07	-0.17	11.67	1.01	-0.25	0.08	-17.3	-4.8	33.2	9.4	8.6	1.8	-0.53	-0.44	0.08	1.18	-0.00	-0.00
5	5	0.09	-0.04	5.37	0.16	-0.12	0.02	-5.3	-0.4	22.3	4.7	1.2	0.3	-1.36	-0.53	0.12	1.17	-0.00	-0.00
	10	0.02	-0.06	6.26	0.25	-0.14	0.04	-8.3	-0.9	24.9	5.8	1.8	0.5	-1.34	-0.54	0.12	1.17	-0.00	-0.00
	15	-0.11	-0.10	7.08	0.35	-0.15	0.05	-11.8	-1.6	25.6	6.8	2.9	0.7	-1.32	-0.55	0.12	1.17	-0.00	-0.00
	20	-0.29	-0.14	7.86	0.46	-0.15	0.07	-14.6	-2.6	26.5	7.5	4.5	1.0	-1.34	-0.57	0.12	1.17	-0.00	-0.00
6	5	-0.38	-0.05	12.20	0.92	-0.50	0.01	-17.0	-0.9	46.7	12.9	2.2	0.6	-0.40	-0.49	0.07	1.18	-0.00	-0.00
	10	-1.76	-0.08	16.67	1.85	-0.61	0.02	-37.4	-3.0	71.4	20.6	5.7	1.4	-0.24	-0.50	0.07	1.18	-0.00	-0.00
	15	-4.41	-0.12	21.67	3.18	-0.63	0.03	-66.6	-8.2	106.2	30.3	13.0	3.3	-0.23	-0.48	0.06	1.18	-0.00	-0.00
	20	-8.17	-0.18	27.76	4.82	-0.57	0.04	-92.8	-15.3	134.8	39.4	22.6	5.6	-0.23	-0.48	0.06	1.18	-0.00	-0.00
7	5	-0.18	-0.05	9.68	0.74	-0.43	0.01	-9.3	-0.7	26.5	8.5	1.6	0.5	-1.37	-0.52	0.11	1.17	-0.00	-0.00
	10	-0.73	-0.09	12.33	1.26	-0.52	0.03	-17.1	-2.2	33.3	11.8	4.0	1.2	-1.28	-0.54	0.11	1.18	-0.00	-0.00
	15	-1.83	-0.14	14.94	1.99	-0.54	0.04	-25.6	-5.0	42.2	15.0	8.0	2.4	-1.24	-0.55	0.11	1.18	-0.00	-0.00
	20	-3.35	-0.24	18.00	2.80	-0.50	0.08	-30.7	-11.7	46.1	16.6	16.5	4.9	-1.28	-0.55	0.12	1.18	-0.00	-0.00
8	5	0.02	-0.03	4.78	0.24	-0.14	0.02	-4.9	-0.3	17.9	4.5	1.1	0.3	-2.55	-0.51	0.13	1.17	-0.00	-0.00
	10	-0.06	-0.06	5.59	0.34	-0.16	0.03	-7.0	-0.8	19.5	5.4	1.7	0.5	-2.53	-0.52	0.13	1.17	-0.00	-0.00
	15	-0.19	-0.09	6.30	0.45	-0.17	0.04	-9.5	-1.4	20.3	6.3	2.3	0.7	-2.51	-0.53	0.13	1.17	-0.00	-0.00
	20	-0.37	-0.13	7.01	0.57	-0.17	0.06	-11.9	-2.2	19.9	7.0	3.7	1.0	-2.50	-0.55	0.13	1.17	-0.00	-0.00
9	5	-0.79	-0.06	12.57	1.78	-0.59	-0.03	-21.7	-1.8	41.7	15.7	2.8	1.1	-14.01	-0.31	0.36	1.17	-0.01	0.00
	10	-2.80	-0.09	16.53	3.09	-0.70	-0.03	-47.5	-5.2	60.7	25.5	6.7	2.6	-14.30	-0.27	0.37	1.17	-0.02	0.00
	15	-7.30	-0.16	21.73	5.27	-0.67	-0.02	-64.2	-9.8	74.7	30.5	11.7	4.5	-14.72	-0.26	0.38	1.17	-0.02	0.00
	20	-13.20	-0.34	28.17	7.79	-0.47	0.06	-120.8	3.9	132.5	53.6	-3.0	-1.3	-15.35	-0.25	0.39	1.18	-0.02	0.00

TABLE A(III)-15. (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.44	-0.04	6.94	1.27	-0.24	-0.00	-13.2	-0.9	31.1	12.7	1.8	0.8	-14.24	-0.14	0.40	1.16	-0.01	0.00
	10	-1.18	-0.08	9.43	1.97	-0.28	0.01	-27.6	-3.0	40.3	19.4	3.7	1.8	-14.54	-0.10	0.41	1.17	-0.01	0.00
	15	-2.83	-0.17	11.54	3.02	-0.26	0.04	-43.6	-7.6	50.6	25.5	9.1	3.9	-14.76	-0.07	0.41	1.17	-0.01	0.00
	20	-5.61	-0.35	14.09	4.43	-0.06	0.13	-57.5	-13.4	63.0	30.8	15.3	6.5	-15.09	-0.05	0.41	1.17	-0.01	0.00
11	5	-0.20	-0.03	4.33	0.88	-0.11	0.01	-9.1	-0.5	21.8	10.2	1.1	0.5	-10.12	-0.26	0.38	1.16	-0.01	0.00
	10	-0.47	-0.06	5.40	1.20	-0.12	0.02	-17.3	-1.3	27.9	14.8	1.8	1.0	-10.14	-0.24	0.37	1.16	-0.01	0.00
	15	-1.01	-0.11	6.55	1.65	-0.12	0.05	-27.7	-2.7	34.5	19.8	3.5	1.7	-10.10	-0.24	0.37	1.17	-0.01	0.00
	20	-1.96	-0.20	7.71	2.27	-0.08	0.09	-39.4	-5.9	42.8	25.0	7.4	3.3	-10.05	-0.24	0.37	1.17	-0.01	0.00
12	5	-0.04	-0.03	4.06	0.33	-0.13	0.02	-4.8	-0.3	14.8	5.0	0.9	0.3	-3.82	-0.32	0.19	1.16	-0.01	-0.00
	10	-0.12	-0.05	4.67	0.42	-0.15	0.03	-6.7	-0.7	16.4	6.0	1.5	0.5	-3.85	-0.33	0.20	1.16	-0.01	-0.00
	15	-0.25	-0.08	5.25	0.54	-0.15	0.05	-8.9	-1.2	17.3	6.9	2.3	0.7	-3.87	-0.33	0.20	1.16	-0.01	0.00
	20	-0.44	-0.12	5.82	0.69	-0.14	0.06	-10.7	-1.9	18.4	7.6	3.3	1.0	-3.89	-0.34	0.20	1.17	-0.01	0.00
13	5	-0.05	-0.03	2.35	0.41	-0.02	0.02	-5.9	-0.3	15.6	6.7	0.7	0.3	-7.34	-0.17	0.38	1.15	-0.01	0.00
	10	-0.14	-0.04	2.78	0.52	-0.01	0.03	-8.9	-0.7	18.7	8.7	1.1	0.5	-7.37	-0.16	0.38	1.15	-0.01	0.00
	15	-0.28	-0.07	3.22	0.67	-0.01	0.04	-12.7	-1.0	21.4	10.7	1.5	0.7	-7.37	-0.15	0.38	1.16	-0.01	0.00
	20	-0.49	-0.11	3.64	0.84	0.00	0.06	-17.2	-1.4	25.0	13.0	2.3	0.8	-7.38	-0.16	0.38	1.16	-0.01	0.00
14	5	-0.05	-0.03	2.18	0.43	-0.01	0.02	-6.6	-0.3	16.7	7.4	0.7	0.3	-7.56	-0.19	0.37	1.15	-0.01	0.00
	10	-0.15	-0.05	2.69	0.56	-0.01	0.03	-10.6	-0.7	20.5	9.9	1.0	0.5	-7.58	-0.19	0.37	1.15	-0.01	0.00
	15	-0.32	-0.08	3.18	0.72	-0.00	0.05	-15.4	-1.1	23.7	12.5	1.6	0.7	-7.57	-0.19	0.37	1.16	-0.01	0.00
	20	-0.55	-0.12	3.61	0.90	0.02	0.07	-21.1	-1.5	28.3	15.3	2.4	0.9	-7.53	-0.18	0.37	1.16	-0.01	0.00
15	5	-0.01	-0.03	2.05	0.49	-0.03	0.01	-4.4	-0.4	10.7	5.4	0.8	0.4	-5.44	-0.34	0.31	1.14	-0.01	0.00
	10	-0.05	-0.05	2.55	0.58	-0.04	0.03	-5.6	-0.9	11.3	6.3	1.3	0.8	-5.41	-0.34	0.31	1.15	-0.01	0.00
	15	-0.11	-0.09	2.99	0.68	-0.04	0.05	-6.6	-1.5	10.6	6.7	2.2	1.1	-5.35	-0.36	0.31	1.15	-0.01	0.00
	20	-0.20	-0.13	3.36	0.79	-0.01	0.07	-7.0	-2.5	9.6	6.6	3.4	1.7	-5.29	-0.37	0.31	1.16	-0.01	0.00
16	5	0.04	-0.03	4.29	0.21	-0.06	0.02	-5.3	-0.3	22.9	5.1	0.8	0.2	-3.41	-0.34	0.18	1.17	-0.00	-0.00
	10	-0.03	-0.05	4.84	0.28	-0.06	0.03	-8.5	-0.5	26.3	6.4	1.1	0.3	-3.40	-0.34	0.19	1.17	-0.00	-0.00
	15	-0.15	-0.07	5.36	0.37	-0.05	0.04	-12.8	-0.8	28.6	7.9	1.5	0.4	-3.43	-0.35	0.19	1.17	-0.00	-0.00
	20	-0.31	-0.10	5.90	0.47	-0.04	0.06	-16.7	-1.2	31.2	9.0	2.3	0.5	-3.46	-0.36	0.19	1.17	-0.00	-0.00
17	5	0.04	-0.03	3.97	0.18	-0.05	0.02	-4.1	-0.2	19.2	4.0	0.8	0.2	-3.51	-0.49	0.17	1.16	-0.00	-0.00
	10	0.01	-0.05	4.45	0.23	-0.05	0.03	-6.2	-0.5	21.5	4.9	1.2	0.3	-3.44	-0.50	0.18	1.17	-0.00	-0.00
	15	-0.05	-0.07	4.88	0.29	-0.05	0.04	-8.8	-0.9	23.1	5.8	1.5	0.4	-3.47	-0.51	0.18	1.17	-0.00	-0.00
	20	-0.15	-0.11	5.33	0.36	-0.04	0.05	-12.0	-1.4	23.7	6.8	2.0	0.6	-3.50	-0.53	0.18	1.17	-0.00	-0.00
18	5	-0.07	-0.02	2.53	0.27	-0.01	0.01	-4.3	-0.2	18.1	4.7	0.6	0.2	-8.38	-0.14	0.34	1.15	-0.00	0.00
	10	-0.14	-0.03	2.99	0.34	-0.01	0.02	-6.3	-0.3	20.6	5.6	0.8	0.2	-8.39	-0.14	0.34	1.16	-0.00	0.00
	15	-0.26	-0.05	3.40	0.43	-0.01	0.03	-8.8	-0.5	22.6	6.7	1.0	0.3	-8.43	-0.14	0.34	1.16	-0.00	0.00
	20	-0.41	-0.07	3.79	0.53	-0.00	0.04	-11.9	-0.9	23.9	7.8	1.3	0.4	-8.46	-0.14	0.34	1.16	-0.00	0.00

TABLE A(III)-15 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.04	-0.03	2.98	0.31	-0.03	0.02	-5.8	-0.3	16.3	5.8	0.7	0.2	-7.12	-0.25	0.28	1.15	-0.00	0.00
	10	-0.13	-0.05	3.30	0.40	-0.03	0.03	-8.4	-0.6	19.0	7.1	0.9	0.4	-7.17	-0.25	0.28	1.16	-0.00	0.00
	15	-0.25	-0.07	3.57	0.49	-0.02	0.04	-11.6	-0.9	21.0	8.5	1.1	0.5	-7.21	-0.25	0.28	1.16	-0.00	0.00
	20	-0.41	-0.10	3.87	0.60	-0.01	0.06	-15.4	-1.2	22.2	10.0	1.7	0.6	-7.23	-0.26	0.28	1.16	-0.00	0.00
20	5	-0.02	-0.03	3.12	0.39	-0.06	0.02	-6.3	-0.3	15.5	6.7	0.7	0.3	-5.92	-0.23	0.26	1.15	-0.01	-0.00
	10	-0.12	-0.05	3.54	0.50	-0.06	0.03	-9.6	-0.7	18.4	8.6	1.1	0.5	-5.94	-0.23	0.26	1.16	-0.01	0.00
	15	-0.28	-0.08	3.93	0.64	-0.05	0.05	-13.6	-1.1	21.2	10.5	1.7	0.7	-5.94	-0.23	0.26	1.16	-0.01	0.00
	20	-0.52	-0.12	4.31	0.82	-0.04	0.07	-18.5	-1.6	25.0	12.8	2.6	0.9	-5.93	-0.23	0.26	1.16	-0.01	0.00
21	5	-0.03	-0.03	2.81	0.43	-0.06	0.02	-5.4	-0.4	12.7	6.3	0.7	0.3	-5.44	-0.22	0.25	1.15	-0.01	0.00
	10	-0.11	-0.05	3.20	0.53	-0.06	0.03	-7.9	-0.8	14.6	7.7	1.3	0.6	-5.46	-0.21	0.25	1.15	-0.01	0.00
	15	-0.23	-0.08	3.54	0.66	-0.05	0.05	-10.5	-1.3	16.0	9.0	2.1	0.9	-5.43	-0.22	0.25	1.16	-0.01	0.00
	20	-0.43	-0.12	3.87	0.81	-0.02	0.07	-12.9	-2.1	17.4	10.0	3.2	1.3	-5.41	-0.22	0.25	1.16	-0.01	0.00
22	5	0.04	-0.02	4.40	0.16	-0.11	0.01	-3.1	-0.2	16.7	2.9	0.8	0.1	-5.09	-0.30	0.21	1.16	-0.01	-0.00
	10	0.01	-0.03	4.82	0.19	-0.12	0.02	-4.5	-0.3	18.0	3.4	1.0	0.2	-5.08	-0.30	0.21	1.16	-0.01	-0.00
	15	-0.05	-0.05	5.20	0.24	-0.12	0.02	-6.1	-0.5	18.7	3.8	1.1	0.2	-5.13	-0.31	0.21	1.16	-0.01	0.00
	20	-0.14	-0.07	5.57	0.29	-0.12	0.03	-7.9	-0.7	18.9	4.3	1.2	0.3	-5.17	-0.31	0.21	1.17	-0.01	0.00
23	5	0.04	-0.02	2.62	0.07	0.00	0.01	-3.4	-0.2	16.3	2.7	0.6	0.1	-3.42	-0.36	0.16	1.16	0.00	-0.00
	10	0.03	-0.03	2.79	0.09	0.01	0.02	-4.7	-0.3	17.4	3.1	0.7	0.1	-3.39	-0.37	0.17	1.16	0.00	-0.00
	15	0.01	-0.05	2.95	0.10	0.01	0.02	-6.2	-0.5	17.8	3.5	0.8	0.2	-3.39	-0.38	0.17	1.16	0.00	-0.00
	20	-0.02	-0.06	3.11	0.12	0.02	0.03	-7.7	-0.6	17.8	3.9	1.0	0.2	-3.41	-0.39	0.17	1.16	0.00	-0.00
24	5	0.03	-0.03	3.94	0.14	-0.06	0.02	-4.0	-0.2	18.2	3.5	0.8	0.2	-4.09	-0.45	0.18	1.16	-0.00	-0.00
	10	-0.00	-0.04	4.34	0.18	-0.06	0.03	-6.0	-0.5	20.1	4.2	1.1	0.2	-4.01	-0.47	0.18	1.17	-0.00	-0.00
	15	-0.06	-0.07	4.69	0.22	-0.05	0.04	-8.2	-0.7	20.8	4.8	1.3	0.3	-4.03	-0.48	0.18	1.17	-0.00	-0.00
	20	-0.15	-0.09	5.05	0.27	-0.05	0.05	-10.5	-1.1	20.8	5.4	1.6	0.4	-4.07	-0.49	0.18	1.17	-0.00	-0.00
25	5	0.04	-0.03	3.51	0.28	-0.09	0.01	-3.8	-0.2	14.2	4.2	0.8	0.2	-6.19	-0.41	0.23	1.15	-0.01	-0.00
	10	-0.00	-0.04	3.93	0.34	-0.09	0.02	-5.8	-0.5	15.7	5.1	1.2	0.3	-6.24	-0.41	0.23	1.16	-0.01	0.00
	15	-0.06	-0.07	4.32	0.41	-0.10	0.04	-7.8	-0.9	16.6	5.8	1.5	0.5	-6.28	-0.42	0.23	1.16	-0.01	0.00
	20	-0.17	-0.10	4.70	0.49	-0.09	0.05	-10.3	-1.4	16.4	6.5	2.2	0.7	-6.33	-0.43	0.23	1.16	-0.01	0.00
26	5	-0.04	-0.03	3.62	0.51	-0.15	0.01	-3.8	-0.4	10.2	4.5	0.9	0.4	-7.56	-0.42	0.29	1.14	-0.01	0.00
	10	-0.10	-0.05	4.21	0.61	-0.17	0.02	-5.0	-0.9	10.6	5.0	1.5	0.7	-7.55	-0.43	0.29	1.15	-0.01	0.00
	15	-0.18	-0.09	4.73	0.72	-0.18	0.04	-6.1	-1.6	10.0	5.2	2.2	1.0	-7.55	-0.44	0.29	1.15	-0.01	0.00
	20	-0.29	-0.14	5.21	0.84	-0.17	0.06	-6.6	-2.4	8.8	5.2	3.2	1.4	-7.61	-0.45	0.29	1.15	-0.01	0.00
27	5	-0.07	-0.04	3.39	1.04	-0.13	-0.02	-4.1	-0.6	10.8	5.6	1.2	0.7	-6.78	-0.59	0.36	1.14	-0.01	0.00
	10	-0.17	-0.08	4.53	1.33	-0.17	-0.01	-5.5	-1.6	10.2	5.9	2.3	1.3	-6.58	-0.62	0.36	1.15	-0.01	0.00
	15	-0.33	-0.14	5.56	1.63	-0.18	0.02	-5.7	-2.9	8.4	5.5	3.8	2.0	-6.34	-0.65	0.35	1.15	-0.01	0.00
	20	-0.49	-0.23	6.24	1.85	-0.13	0.06	-3.3	-5.1	5.3	3.9	6.0	3.1	-6.25	-0.67	0.35	1.16	-0.01	0.00

TABLE A(III)-16. SPRING PLOW CORN (A AND B SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.79	-3.43	-1.73	52.21	10	5	2.56	-4.08	-2.48	58.80	19	5	3.90	-6.77	-3.87	74.89
	10	1.70	-3.34	-1.58	40.39		10	2.49	-4.00	-2.22	44.30		10	3.90	-6.93	-3.81	67.84
	15	1.62	-3.26	-1.47	31.53		15	2.35	-3.83	-2.03	35.16		15	3.86	-6.96	-3.73	62.80
	20	1.53	-3.08	-1.37	23.77		20	2.26	-3.63	-1.87	27.55		20	3.82	-7.03	-3.69	58.73
2	5	2.68	-4.77	-2.65	58.77	11	5	2.95	-4.25	-2.90	67.20	20	5	3.74	-5.42	-3.71	74.14
	10	2.61	-4.65	-2.51	48.44		10	2.86	-4.11	-2.66	54.47		10	3.74	-5.54	-3.63	65.56
	15	2.53	-4.59	-2.40	40.86		15	2.82	-4.16	-2.49	46.37		15	3.72	-5.61	-3.54	59.70
	20	2.45	-4.41	-2.31	35.15		20	2.74	-4.14	-2.36	39.80		20	3.67	-5.62	-3.42	54.73
3	5	3.45	-5.06	-3.45	73.14	12	5	3.31	-4.71	-3.28	71.83	21	5	3.98	-5.13	-3.95	74.97
	10	3.49	-5.31	-3.48	67.62		10	3.37	-4.92	-3.28	63.48		10	4.00	-5.30	-3.91	66.71
	15	3.48	-5.37	-3.48	64.40		15	3.39	-5.07	-3.24	57.76		15	3.98	-5.40	-3.84	61.00
	20	3.47	-5.47	-3.47	61.72		20	3.37	-5.22	-3.16	53.05		20	3.93	-5.42	-3.77	56.55
4	5	2.91	-5.01	-2.88	64.38	13	5	3.82	-3.71	-3.78	75.42	22	5	3.50	-6.08	-3.50	76.43
	10	2.94	-5.26	-2.84	54.93		10	3.81	-3.70	-3.67	66.76		10	3.52	-6.30	-3.51	70.96
	15	2.90	-5.32	-2.74	48.21		15	3.77	-3.75	-3.52	60.84		15	3.52	-6.33	-3.51	67.52
	20	2.86	-5.37	-2.74	43.08		20	3.74	-3.86	-3.41	56.11		20	3.51	-6.42	-3.51	64.68
5	5	3.23	-5.52	-3.21	68.10	14	5	3.89	-4.48	-3.85	74.51	23	5	4.56	-5.85	-4.55	83.44
	10	3.25	-5.66	-3.18	60.35		10	3.89	-4.63	-3.72	65.66		10	4.58	-5.99	-4.55	79.08
	15	3.24	-5.77	-3.17	55.12		15	3.86	-4.70	-3.61	59.81		15	4.59	-6.06	-4.58	76.24
	20	3.23	-5.80	-3.15	50.73		20	3.80	-4.78	-3.49	55.11		20	4.59	-6.10	-4.58	73.81
6	5	1.80	-3.55	-1.70	47.65	15	5	3.92	-3.50	-3.90	72.87	24	5	3.68	-6.31	-3.67	75.45
	10	1.73	-3.61	-1.48	33.54		10	3.95	-3.80	-3.88	65.11		10	3.69	-6.53	-3.65	69.22
	15	1.63	-3.45	-1.27	24.71		15	3.95	-3.99	-3.87	60.40		15	3.68	-6.60	-3.65	65.26
	20	1.54	-3.29	-1.17	18.17		20	3.93	-4.06	-3.86	56.73		20	3.65	-6.60	-3.64	62.00
7	5	2.38	-4.58	-2.32	56.43	16	5	3.14	-4.79	-3.11	70.65	25	5	3.88	-6.80	-3.86	77.97
	10	2.43	-4.85	-2.20	43.28		10	3.12	-4.95	-3.04	63.32		10	3.90	-6.85	-3.85	70.51
	15	2.38	-4.92	-1.98	34.42		15	3.09	-4.96	-2.98	57.88		15	3.90	-6.97	-3.85	65.40
	20	2.32	-4.86	-1.81	27.39		20	3.08	-5.05	-2.99	53.92		20	3.88	-7.02	-3.83	61.35
8	5	3.31	-5.54	-3.27	69.84	17	5	3.42	-6.04	-3.41	73.15	26	5	3.82	-5.62	-3.80	73.32
	10	3.38	-5.81	-3.28	61.90		10	3.44	-6.26	-3.39	66.21		10	3.89	-5.96	-3.84	65.10
	15	3.39	-5.98	-3.25	56.47		15	3.42	-6.33	-3.36	61.26		15	3.92	-6.22	-3.87	60.44
	20	3.38	-6.14	-3.24	52.33		20	3.41	-6.38	-3.34	56.94		20	3.91	-6.24	-3.87	56.77
9	5	2.16	-4.19	-2.04	48.18	18	5	3.99	-6.82	-3.99	78.90	27	5	3.64	-5.34	-3.62	67.66
	10	2.02	-4.09	-1.66	32.45		10	3.98	-6.93	-3.94	72.40		10	3.69	-5.62	-3.64	58.77
	15	1.93	-3.97	-1.53	23.95		15	3.93	-6.93	-3.88	67.59		15	3.73	-5.95	-3.63	53.18
	20	1.82	-3.76	-1.35	17.12		20	3.90	-6.98	-3.85	63.55		20	3.75	-6.15	-3.62	48.89

TABLE A(III)-17. SPRING PLOW CORN, SPRING FERTILIZATION (A AND B SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	0.16	-0.16	5.72	0.27	-0.21	0.07	-12.8	-0.6	38.5	8.5	1.9	0.4	-0.40	-0.19	1.05	1.16	-0.05	0.00
	10	0.28	-0.31	5.70	0.21	0.08	0.15	-15.6	-0.9	47.0	10.5	2.8	0.6	-0.34	-0.20	1.03	1.16	-0.05	0.00
	15	0.30	-0.44	5.35	0.17	0.49	0.24	-19.0	-1.4	57.0	12.8	4.5	1.0	-0.41	-0.19	1.02	1.17	-0.05	0.00
	20	0.26	-0.60	5.62	0.21	0.96	0.34	-23.7	-2.5	70.6	15.8	8.2	1.8	-0.46	-0.18	1.02	1.17	-0.05	0.00
2	5	-0.02	-0.11	2.44	0.15	0.03	0.05	-9.5	-0.8	28.8	5.4	2.6	0.5	-0.16	-0.24	0.49	1.17	0.00	0.00
	10	-0.16	-0.19	2.67	0.20	0.20	0.08	-11.0	-1.2	33.2	6.2	3.8	0.7	-0.07	-0.24	0.45	1.17	0.01	0.00
	15	-0.40	-0.24	2.89	0.28	0.43	0.12	-12.2	-1.7	37.0	6.9	5.5	1.0	0.12	-0.26	0.39	1.17	0.01	0.00
	20	-0.65	-0.30	3.52	0.41	0.63	0.15	-13.1	-2.5	39.3	7.3	7.9	1.4	0.08	-0.25	0.38	1.17	0.01	0.00
3	5	-0.04	-0.07	1.68	0.08	-0.03	0.02	-5.4	-0.7	13.8	2.1	1.5	0.2	-1.29	-0.36	0.47	1.15	0.01	0.00
	10	0.01	-0.11	1.61	0.07	0.04	0.03	-6.3	-1.0	14.7	2.3	1.9	0.3	-1.10	-0.39	0.43	1.15	0.01	0.00
	15	0.04	-0.16	1.53	0.06	0.13	0.05	-7.1	-1.2	15.4	2.4	2.1	0.3	-1.10	-0.40	0.41	1.16	0.01	0.00
	20	0.08	-0.21	1.38	0.06	0.22	0.06	-7.9	-1.4	16.1	2.5	2.3	0.3	-1.02	-0.41	0.38	1.16	0.02	0.00
4	5	-0.17	-0.09	3.21	0.22	-0.12	0.03	-8.7	-1.0	19.2	4.3	1.8	0.4	-2.63	-0.35	0.93	1.15	-0.02	0.00
	10	-0.06	-0.17	3.28	0.20	0.00	0.06	-10.9	-1.7	22.0	4.9	2.7	0.6	-2.26	-0.39	0.90	1.15	-0.02	0.00
	15	0.04	-0.28	3.22	0.19	0.15	0.10	-13.4	-2.2	24.6	5.4	3.5	0.7	-2.24	-0.40	0.88	1.15	-0.02	0.00
	20	0.14	-0.40	3.20	0.19	0.34	0.13	-15.0	-2.9	26.0	5.7	4.7	1.0	-2.15	-0.42	0.86	1.16	-0.02	0.00
5	5	-0.03	-0.08	1.84	0.11	-0.04	0.03	-7.6	-0.9	14.8	3.3	1.6	0.3	-2.73	-0.55	0.55	1.15	0.01	0.00
	10	0.04	-0.15	1.81	0.11	0.06	0.05	-8.9	-1.4	16.4	3.7	2.2	0.5	-2.50	-0.58	0.52	1.15	0.01	0.00
	15	0.10	-0.22	1.58	0.10	0.18	0.07	-10.0	-1.9	17.4	3.9	2.8	0.6	-2.43	-0.60	0.49	1.16	0.01	0.00
	20	0.11	-0.30	1.47	0.11	0.31	0.10	-11.2	-2.4	18.3	4.0	3.5	0.7	-2.63	-0.60	0.48	1.16	0.02	0.00
6	5	-0.23	-0.13	5.42	0.33	-0.21	0.06	-19.6	-1.5	38.7	9.9	2.3	0.6	-3.78	-0.38	1.09	1.16	-0.02	0.00
	10	0.17	-0.35	6.90	0.28	-0.12	0.14	-30.5	-2.9	53.5	13.4	4.3	1.0	-1.54	-0.59	1.05	1.17	-0.02	0.00
	15	0.29	-0.62	7.56	0.30	0.20	0.23	-42.2	-5.1	68.7	17.1	7.5	1.8	-1.02	-0.63	1.03	1.17	-0.02	0.00
	20	0.20	-0.96	8.49	0.41	0.60	0.35	-53.4	-9.4	83.6	20.8	13.9	3.3	-0.19	-0.70	1.03	1.17	-0.02	0.00
7	5	-0.31	-0.08	3.35	0.36	-0.12	0.05	-11.0	-1.1	22.4	6.8	1.8	0.5	-5.01	-0.35	1.09	1.15	-0.02	0.00
	10	-0.28	-0.19	3.82	0.40	-0.03	0.09	-15.3	-2.2	28.2	8.4	3.3	0.9	-4.31	-0.42	1.07	1.16	-0.02	0.00
	15	-0.34	-0.33	4.37	0.50	0.12	0.14	-20.1	-3.5	34.0	10.1	5.1	1.4	-3.94	-0.47	1.05	1.16	-0.01	0.00
	20	-0.54	-0.51	4.97	0.63	0.36	0.21	-24.6	-5.6	38.9	11.5	8.2	2.3	-3.88	-0.48	1.03	1.16	-0.01	0.00
8	5	-0.22	-0.05	1.86	0.20	-0.06	0.02	-7.0	-0.8	11.9	3.3	1.2	0.3	-8.15	-0.13	0.84	1.13	-0.02	0.00
	10	-0.23	-0.11	1.89	0.22	0.02	0.04	-8.0	-1.2	13.0	3.5	1.7	0.4	-8.11	-0.14	0.82	1.13	-0.01	0.00
	15	-0.24	-0.17	1.80	0.23	0.11	0.06	-8.8	-1.6	13.9	3.7	2.1	0.6	-8.20	-0.14	0.82	1.13	-0.01	0.00
	20	-0.27	-0.23	1.70	0.25	0.21	0.08	-9.4	-2.0	14.6	3.9	2.6	0.7	-8.67	-0.11	0.80	1.14	-0.01	0.00
9	5	-0.44	-0.18	2.78	0.47	0.04	0.08	-26.0	-2.4	34.5	13.1	2.9	1.0	-17.76	-0.18	0.99	1.15	0.00	0.00
	10	-0.67	-0.35	2.58	0.65	0.26	0.14	-40.5	-4.8	49.8	18.4	5.5	2.0	-19.63	0.01	1.03	1.15	0.00	0.00
	15	-1.25	-0.60	2.63	0.93	0.61	0.24	-52.3	-8.8	62.0	22.7	10.0	3.6	-21.43	0.16	1.05	1.16	-0.00	0.00
	20	-1.74	-1.05	3.02	1.14	1.12	0.41	-74.1	-10.1	84.3	30.9	12.2	4.1	-21.97	0.16	1.07	1.16	-0.00	0.00

TABLE A (III)-17 (CONT)

REGION			DISSOLVED N IN RUNOFF							DISSOLVED N IN PERCOLATION							DISSOLVED P IN RUNOFF			
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.17	-0.13	2.43	0.39	-0.03	0.07	-15.9	-1.5	21.3	9.6	1.8	0.8	-15.56	-0.28	0.92	1.14	0.01	0.00
	10	-0.23	-0.25	2.34	0.50	0.09	0.12	-22.1	-2.8	27.7	12.3	3.2	1.3	-15.76	-0.24	0.93	1.15	0.01	0.00
	15	-0.34	-0.41	2.20	0.59	0.30	0.19	-27.8	-4.6	33.5	14.6	5.1	2.1	-16.13	-0.20	0.93	1.15	0.01	0.00
	20	-0.58	-0.65	2.20	0.72	0.59	0.29	-32.6	-8.1	38.2	16.5	8.9	3.7	-16.38	-0.19	0.95	1.16	0.01	0.00
11	5	-0.07	-0.10	2.29	0.32	-0.09	0.05	-9.5	-0.9	13.2	6.6	1.2	0.5	-8.37	-0.69	0.79	1.13	0.00	0.00
	10	-0.05	-0.17	2.36	0.36	-0.03	0.09	-12.5	-1.5	16.2	8.0	1.8	0.8	-7.94	-0.71	0.79	1.14	0.00	0.00
	15	0.02	-0.26	2.25	0.38	0.09	0.13	-15.0	-2.2	18.8	9.1	2.4	1.1	-7.47	-0.75	0.78	1.14	0.01	0.00
	20	0.06	-0.39	2.19	0.42	0.24	0.18	-17.6	-3.0	21.4	10.2	3.3	1.5	-7.58	-0.75	0.78	1.15	0.01	0.00
12	5	-0.10	-0.05	2.06	0.19	-0.09	0.03	-4.8	-0.6	10.3	3.4	1.0	0.3	-5.53	-0.30	0.91	1.12	-0.01	0.00
	10	-0.09	-0.09	2.01	0.20	-0.03	0.05	-5.5	-1.0	11.3	3.7	1.5	0.4	-5.71	-0.28	0.90	1.13	-0.01	0.00
	15	-0.08	-0.14	2.01	0.21	0.04	0.07	-6.4	-1.3	12.3	4.0	1.9	0.5	-5.78	-0.29	0.90	1.13	-0.01	0.00
	20	-0.05	-0.19	1.98	0.21	0.12	0.09	-7.4	-1.6	13.2	4.2	2.2	0.7	-5.76	-0.30	0.88	1.13	-0.01	0.00
13	3	-0.06	-0.05	1.17	0.18	-0.03	0.04	-4.5	-0.7	7.7	3.4	1.0	0.4	-8.05	-0.24	0.74	1.10	-0.00	0.00
	10	-0.07	-0.09	1.19	0.20	0.01	0.05	-5.3	-1.0	8.6	3.8	1.3	0.5	-8.03	-0.24	0.74	1.11	-0.00	0.00
	15	-0.04	-0.13	1.16	0.21	0.07	0.07	-6.2	-1.2	9.4	4.1	1.5	0.6	-7.93	-0.24	0.74	1.11	-0.00	0.00
	20	-0.01	-0.19	1.12	0.21	0.14	0.09	-7.0	-1.4	10.2	4.3	1.7	0.7	-7.89	-0.25	0.73	1.12	-0.00	0.00
14	5	-0.08	-0.05	1.05	0.20	-0.03	0.03	-4.7	-0.8	7.5	3.5	1.0	0.4	-9.58	-0.12	0.69	1.10	-0.01	0.00
	10	-0.09	-0.09	1.09	0.22	0.01	0.05	-5.5	-1.1	8.3	3.8	1.4	0.6	-9.50	-0.13	0.69	1.10	-0.01	0.00
	15	-0.06	-0.14	1.06	0.23	0.08	0.07	-6.3	-1.4	9.1	4.1	1.7	0.7	-9.30	-0.15	0.67	1.11	-0.00	0.00
	20	-0.03	-0.19	1.01	0.24	0.15	0.09	-6.9	-1.6	9.7	4.3	1.9	0.8	-9.11	-0.16	0.66	1.11	-0.00	0.00
15	5	-0.05	-0.05	1.07	0.20	-0.03	0.03	-3.2	-0.6	6.0	3.2	0.9	0.4	-6.94	-0.33	0.69	1.09	0.00	0.00
	10	-0.02	-0.08	1.10	0.21	0.00	0.05	-3.7	-1.0	6.4	3.4	1.3	0.6	-6.73	-0.35	0.69	1.40	0.00	0.00
	15	0.01	-0.12	1.09	0.22	0.05	0.07	-3.9	-1.3	6.6	3.4	1.6	0.7	-6.44	-0.38	0.67	1.10	0.01	0.00
	20	0.06	-0.16	1.07	0.21	0.10	0.09	-4.0	-1.6	6.6	3.4	2.0	0.9	-6.33	-0.40	0.67	1.11	0.01	0.00
16	5	-0.05	-0.06	2.90	0.19	-0.15	0.02	-6.7	-0.7	13.5	3.3	1.3	0.3	-3.15	-0.52	0.79	1.14	-0.02	0.00
	10	0.03	-0.13	2.86	0.18	-0.08	0.04	-8.3	-1.1	15.1	3.6	1.6	0.4	-2.82	-0.56	0.76	1.14	-0.01	0.00
	15	0.06	-0.19	2.87	0.18	0.01	0.06	-10.0	-1.3	16.5	3.9	1.9	0.4	-2.87	-0.57	0.75	1.14	-0.01	0.00
	20	0.04	-0.25	2.77	0.19	0.12	0.08	-11.2	-1.5	17.5	4.1	2.2	0.5	-3.09	-0.56	0.72	1.15	-0.01	0.00
17	5	-0.14	-0.06	1.78	0.17	-0.07	0.02	-6.3	-0.7	10.7	2.8	1.1	0.3	-7.55	-0.28	0.69	1.13	-0.01	0.00
	10	-0.11	-0.12	1.88	0.18	-0.02	0.04	-7.2	-1.0	11.7	3.1	1.4	0.3	-6.97	-0.34	0.64	1.14	-0.00	0.00
	15	-0.17	-0.17	1.60	0.20	0.09	0.05	-8.1	-1.3	12.5	3.3	1.7	0.4	-7.44	-0.32	0.62	1.14	-0.00	0.00
	20	-0.26	-0.22	1.56	0.23	0.18	0.07	-9.1	-1.6	13.3	3.4	2.0	0.5	-7.82	-0.30	0.61	1.14	-0.00	0.00
18	5	-0.15	-0.04	1.34	0.19	-0.05	0.02	-4.3	-0.6	7.4	2.5	0.9	0.3	-11.31	0.04	0.78	1.10	-0.02	0.00
	10	-0.17	-0.08	1.44	0.21	-0.02	0.03	-4.9	-0.9	7.9	2.6	1.2	0.4	-11.11	0.02	0.75	1.11	-0.02	0.00
	15	-0.21	-0.12	1.37	0.23	0.04	0.04	-5.6	-1.1	8.4	2.8	1.4	0.4	-11.29	0.04	0.74	1.11	-0.02	0.00
	20	-0.26	-0.15	1.27	0.25	0.10	0.05	-6.3	-1.3	8.9	2.9	1.6	0.5	-11.48	0.05	0.71	1.12	-0.01	0.00

TABLE A(III)-17 (CONT)

REGION	AW	DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
		A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.20	-0.05	0.90	0.22	-0.00	0.02	-5.1	-0.8	7.8	3.0	1.0	0.4	-13.58	0.27	0.73	1.10	-0.02	0.00
	10	-0.26	-0.09	0.87	0.26	0.05	0.04	-5.8	-1.1	8.4	3.2	1.3	0.5	-14.07	0.31	0.72	1.10	-0.01	0.00
	15	-0.34	-0.13	0.76	0.29	0.12	0.05	-6.5	-1.3	9.0	3.4	1.6	0.6	-14.41	0.34	0.71	1.11	-0.01	0.00
	20	-0.41	-0.17	0.74	0.32	0.19	0.07	-7.1	-1.6	9.5	3.5	1.8	0.7	-14.53	0.35	0.69	1.12	-0.01	0.00
20	5	-0.06	-0.05	1.35	0.20	-0.05	0.03	-4.5	-0.7	8.1	3.4	1.0	0.4	-7.64	-0.19	0.68	1.11	-0.01	0.00
	10	-0.04	-0.09	1.39	0.22	-0.01	0.05	-5.4	-1.1	9.0	3.7	1.4	0.5	-7.49	-0.20	0.66	1.11	-0.00	0.00
	15	-0.01	-0.14	1.36	0.23	0.06	0.07	-6.2	-1.4	9.8	4.0	1.8	0.6	-7.24	-0.23	0.65	1.12	-0.00	0.00
	20	-0.00	-0.20	1.32	0.24	0.13	0.09	-7.0	-1.7	10.5	4.2	2.1	0.8	-7.23	-0.23	0.63	1.12	-0.00	0.00
21	5	-0.07	-0.04	1.10	0.20	-0.03	0.03	-3.7	-0.7	7.0	3.2	1.0	0.4	-7.30	-0.13	0.69	1.10	-0.00	0.00
	10	-0.07	-0.08	1.11	0.22	0.01	0.05	-4.2	-1.0	7.5	3.4	1.4	0.6	-7.28	-0.13	0.69	1.10	-0.00	0.00
	15	-0.06	-0.12	1.10	0.23	0.07	0.07	-4.4	-1.4	7.8	3.6	1.8	0.7	-7.09	-0.15	0.67	1.11	-0.00	0.00
	20	-0.06	-0.16	1.11	0.24	0.13	0.09	-4.8	-1.7	8.2	3.7	2.2	0.9	-6.95	-0.16	0.66	1.11	-0.00	0.00
22	5	-0.14	-0.04	1.82	0.14	-0.07	0.01	-5.0	-0.6	9.8	2.1	1.0	0.2	-6.05	-0.35	0.74	1.13	-0.01	0.00
	10	-0.11	-0.09	1.92	0.14	-0.04	0.03	-5.6	-0.7	10.4	2.2	1.2	0.2	-5.71	-0.39	0.70	1.13	-0.01	0.00
	15	-0.13	-0.12	1.92	0.15	0.02	0.04	-6.1	-0.9	10.9	2.3	1.4	0.3	-5.80	-0.38	0.69	1.13	-0.01	0.00
	20	-0.15	-0.16	1.78	0.16	0.09	0.05	-6.6	-1.1	11.5	2.4	1.5	0.3	-6.00	-0.38	0.68	1.14	-0.00	0.00
23	5	0.02	-0.04	0.50	0.03	0.01	0.02	-3.5	-0.6	6.9	1.4	1.1	0.2	-4.09	-0.38	0.29	1.13	0.01	0.00
	10	0.04	-0.08	0.48	0.03	0.05	0.02	-4.0	-0.8	7.2	1.5	1.3	0.2	-3.91	-0.41	0.27	1.13	0.02	0.00
	15	0.04	-0.11	0.38	0.03	0.10	0.03	-4.5	-1.0	7.5	1.6	1.5	0.3	-3.97	-0.42	0.27	1.13	0.02	0.00
	20	0.04	-0.14	0.32	0.03	0.15	0.04	-5.0	-1.1	7.8	1.6	1.5	0.3	-4.06	-0.42	0.26	1.13	0.02	0.00
24	5	-0.13	-0.05	1.37	0.13	-0.03	0.02	-5.3	-0.7	9.8	2.3	1.1	0.3	-8.30	-0.20	0.65	1.13	-0.01	0.00
	10	-0.11	-0.10	1.43	0.13	0.01	0.03	-6.2	-1.0	10.5	2.5	1.4	0.3	-7.80	-0.27	0.61	1.13	-0.00	0.00
	15	-0.13	-0.15	1.24	0.14	0.09	0.05	-7.0	-1.2	11.1	2.7	1.7	0.4	-8.02	-0.26	0.59	1.14	0.00	0.00
	20	-0.17	-0.19	1.17	0.15	0.17	0.06	-7.8	-1.4	11.7	2.8	1.8	0.4	-8.23	-0.25	0.57	1.14	0.00	0.00
25	5	-0.18	-0.04	1.45	0.22	-0.05	0.02	-5.0	-0.7	8.0	2.7	1.0	0.3	-12.20	0.02	0.81	1.10	-0.02	0.00
	10	-0.24	-0.08	1.55	0.25	-0.02	0.03	-5.6	-0.9	8.6	2.9	1.3	0.4	-12.43	0.04	0.81	1.11	-0.01	0.00
	15	-0.32	-0.11	1.55	0.28	0.03	0.04	-6.0	-1.2	9.1	3.0	1.6	0.5	-12.74	0.05	0.81	1.11	-0.01	0.00
	20	-0.42	-0.15	1.60	0.31	0.10	0.06	-6.4	-1.5	9.4	3.1	1.9	0.6	-13.09	0.08	0.82	1.12	-0.01	0.00
26	5	-0.23	-0.04	0.89	0.22	-0.01	0.03	-3.9	-0.7	7.4	3.2	1.0	0.4	-15.68	0.23	1.05	1.08	-0.02	0.01
	10	-0.29	-0.07	1.02	0.25	0.02	0.04	-4.6	-1.1	7.6	3.4	1.5	0.6	-15.53	0.22	1.05	1.09	-0.02	0.00
	15	-0.31	-0.11	1.08	0.28	0.07	0.06	-4.8	-1.5	7.6	3.5	1.9	0.8	-15.85	0.23	1.05	1.10	-0.02	0.01
	20	-0.36	-0.15	1.12	0.30	0.14	0.08	-4.6	-2.0	7.6	3.4	2.4	1.0	-16.05	0.24	1.05	1.10	-0.02	0.00
27	5	-0.25	-0.05	1.30	0.29	-0.03	0.04	-4.7	-0.8	8.4	4.6	1.3	0.6	-12.65	-0.15	1.04	1.11	-0.01	0.00
	10	-0.31	-0.08	1.41	0.34	0.00	0.06	-5.0	-1.5	8.6	4.7	2.1	1.0	-12.56	-0.17	1.04	1.11	-0.01	0.00
	15	-0.32	-0.14	1.49	0.36	0.06	0.09	-4.8	-2.3	8.3	4.6	3.0	1.4	-12.15	-0.22	1.04	1.12	-0.00	0.00
	20	-0.31	-0.20	1.48	0.37	0.14	0.12	-4.7	-3.1	7.6	4.1	4.0	1.9	-12.35	-0.22	1.04	1.13	-0.00	0.00

TABLE A (III)-18. SPRING PLOW CORN, FALL FERTILIZATION (A AND B SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	0.04	-0.07	-0.63	0.28	0.63	0.06	-6.3	-0.6	36.1	7.9	1.5	0.4	-0.40	-0.19	-0.01	1.16	0.01	0.00
	10	0.22	-0.19	-0.45	0.21	0.86	0.14	-10.3	-1.1	44.4	10.1	2.6	0.6	-0.34	-0.20	-0.01	1.16	0.01	0.00
	15	0.37	-0.35	-0.30	0.17	1.16	0.23	-16.6	-1.6	55.6	12.6	4.3	1.0	-0.41	-0.19	-0.01	1.17	0.01	0.00
	20	0.45	-0.56	-0.12	0.20	1.58	0.34	-22.8	-2.6	69.6	15.7	7.7	1.8	-0.46	-0.18	-0.01	1.17	0.01	0.00
2	5	0.01	-0.06	2.35	0.15	0.28	0.05	-4.1	-0.8	27.0	4.9	2.1	0.5	-0.16	-0.24	-0.00	1.17	0.01	0.00
	10	0.03	-0.13	2.89	0.18	0.36	0.08	-6.1	-1.4	30.6	5.9	3.5	0.7	-0.07	-0.24	-0.00	1.17	0.01	0.00
	15	-0.02	-0.21	3.47	0.26	0.49	0.12	-9.3	-2.0	34.8	6.7	5.3	1.0	0.12	-0.26	-0.00	1.17	0.01	0.00
	20	-0.16	-0.29	3.86	0.38	0.65	0.15	-12.3	-2.6	38.0	7.3	7.5	1.4	0.08	-0.25	-0.00	1.17	0.01	0.00
3	5	-0.03	-0.02	0.64	0.08	0.23	0.01	-1.0	-0.4	14.6	1.5	1.1	0.2	-1.29	-0.36	-0.00	1.15	0.01	0.00
	10	0.01	-0.04	0.88	0.06	0.25	0.03	-1.2	-0.6	15.2	1.6	1.4	0.3	-1.10	-0.39	-0.00	1.15	0.01	0.00
	15	0.05	-0.07	1.05	0.05	0.27	0.04	-1.6	-0.8	15.3	1.8	1.6	0.3	-1.10	-0.40	-0.00	1.16	0.01	0.00
	20	0.10	-0.10	1.26	0.04	0.29	0.05	-2.1	-1.0	15.4	1.9	1.8	0.3	-1.02	-0.41	0.00	1.16	0.01	0.00
4	5	-0.10	-0.03	-0.07	0.21	0.36	0.03	-2.3	-0.4	19.7	3.5	1.4	0.3	-2.63	-0.35	0.01	1.15	0.01	0.00
	10	-0.04	-0.07	0.12	0.20	0.43	0.05	-2.9	-0.9	21.9	4.0	2.0	0.5	-2.26	-0.39	0.01	1.15	0.01	0.00
	15	0.04	-0.12	0.35	0.18	0.49	0.08	-3.8	-1.5	23.2	4.5	2.8	0.7	-2.24	-0.40	0.02	1.15	0.01	0.00
	20	0.16	-0.20	0.63	0.16	0.56	0.12	-5.0	-2.3	22.4	5.0	4.3	1.0	-2.15	-0.42	0.02	1.16	0.01	0.00
5	5	-0.02	-0.02	0.65	0.11	0.25	0.02	-1.5	-0.4	16.1	2.5	1.3	0.3	-2.73	-0.55	0.04	1.15	0.01	0.00
	10	0.01	-0.05	0.91	0.11	0.27	0.04	-1.6	-0.7	17.4	2.7	1.7	0.4	-2.50	-0.58	0.04	1.15	0.01	0.00
	15	0.06	-0.08	1.23	0.09	0.29	0.06	-1.7	-1.2	18.1	2.9	2.1	0.6	-2.43	-0.60	0.04	1.16	0.01	0.00
	20	0.11	-0.12	1.48	0.09	0.32	0.08	-2.0	-1.7	17.9	3.0	2.7	0.7	-2.63	-0.60	0.04	1.16	0.01	0.00
6	5	-0.17	-0.06	-0.66	0.33	0.51	0.05	-8.2	-0.8	38.1	8.5	1.8	0.5	-3.78	-0.38	-0.01	1.16	0.00	0.00
	10	0.06	-0.18	-0.14	0.28	0.67	0.12	-16.0	-2.0	48.3	12.2	3.7	1.0	-1.54	-0.59	-0.01	1.17	0.00	0.00
	15	0.24	-0.39	0.48	0.28	0.89	0.22	-25.7	-4.3	61.2	16.0	6.8	1.7	-1.02	-0.63	-0.01	1.17	0.01	0.00
	20	0.25	-0.66	1.33	0.40	1.20	0.33	-36.4	-8.8	75.2	19.7	13.0	3.3	-0.19	-0.70	-0.01	1.17	0.01	0.00
7	5	-0.20	-0.04	0.36	0.34	0.32	0.04	-4.6	-0.6	23.0	5.9	1.4	0.5	-5.01	-0.35	0.03	1.15	0.00	0.00
	10	-0.19	-0.10	0.86	0.38	0.38	0.08	-6.9	-1.5	27.0	7.5	2.6	0.9	-4.31	-0.42	0.04	1.16	0.00	0.00
	15	-0.18	-0.20	1.73	0.47	0.43	0.13	-10.4	-2.7	30.5	9.4	4.4	1.4	-3.94	-0.47	0.05	1.16	0.00	0.00
	20	-0.25	-0.34	2.45	0.59	0.55	0.19	-13.1	-5.1	34.2	10.7	7.7	2.2	-3.88	-0.48	0.05	1.16	0.00	0.00
8	5	-0.10	-0.02	0.70	0.18	0.17	0.02	-1.5	-0.3	12.9	2.5	1.1	0.3	-8.15	-0.13	0.11	1.13	-0.00	0.00
	10	-0.09	-0.03	0.87	0.20	0.19	0.03	-1.7	-0.6	14.0	2.7	1.4	0.4	-8.11	-0.14	0.11	1.13	-0.00	0.00
	15	-0.07	-0.06	1.03	0.20	0.22	0.05	-1.8	-0.9	14.8	2.8	1.8	0.5	-8.20	-0.14	0.12	1.13	-0.00	0.00
	20	-0.05	-0.10	1.23	0.21	0.24	0.07	-1.8	-1.3	15.2	2.9	2.1	0.7	-8.67	-0.11	0.13	1.14	-0.00	0.00
9	5	-0.29	-0.08	1.42	0.45	0.26	0.07	-11.8	-1.6	36.0	11.2	2.4	1.0	-17.76	-0.18	0.24	1.15	-0.00	0.00
	10	-0.42	-0.20	2.42	0.60	0.30	0.12	-24.8	-3.9	45.6	16.9	4.7	2.0	-19.63	0.01	0.32	1.15	-0.01	0.00
	15	-0.73	-0.44	3.32	0.84	0.46	0.23	-39.2	-7.7	55.0	21.8	9.4	3.5	-21.43	0.16	0.36	1.16	-0.01	0.00
	20	-1.27	-0.84	3.75	1.09	0.88	0.40	-63.0	-8.6	78.2	30.1	10.8	3.9	-21.97	0.16	0.38	1.16	-0.02	0.00

TABLE A(III)-18 (CONT)

REGION	AW	DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
		A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.17	-0.05	1.13	0.39	0.21	0.05	-6.1	-0.8	24.1	8.2	1.6	0.7	-15.56	-0.28	0.31	1.14	-0.00	0.00
	10	-0.18	-0.12	1.56	0.49	0.28	0.10	-9.8	-2.1	29.2	10.7	2.4	1.3	-15.76	-0.24	0.32	1.15	-0.00	0.00
	15	-0.16	-0.25	1.68	0.54	0.39	0.17	-15.4	-3.9	31.3	13.4	4.4	2.1	-16.13	-0.20	0.32	1.15	-0.00	0.00
	20	-0.20	-0.47	1.91	0.63	0.53	0.28	-20.6	-7.4	33.6	15.6	8.5	3.6	-16.38	-0.19	0.31	1.16	-0.00	0.00
11	5	-0.08	-0.04	0.43	0.32	0.19	0.05	-3.5	-0.5	15.1	5.8	1.0	0.5	-8.37	-0.69	0.19	1.13	0.01	0.00
	10	-0.06	-0.07	0.53	0.36	0.24	0.07	-4.6	-0.9	17.8	7.0	1.4	0.8	-7.94	-0.71	0.19	1.14	0.01	0.00
	15	0.01	-0.13	0.69	0.37	0.29	0.11	-5.7	-1.6	19.7	8.0	1.8	1.1	-7.47	-0.75	0.19	1.14	0.01	0.00
	20	0.10	-0.23	0.90	0.40	0.35	0.16	-7.5	-2.6	20.6	9.2	2.7	1.5	-7.58	-0.75	0.20	1.15	0.01	0.00
12	5	-0.08	-0.02	0.13	0.19	0.18	0.02	-2.0	-0.3	11.0	3.0	0.9	0.3	-5.53	-0.30	0.05	1.12	0.01	0.00
	10	-0.07	-0.04	0.18	0.19	0.20	0.04	-2.2	-0.5	12.0	3.2	1.2	0.4	-5.71	-0.28	0.05	1.13	0.01	0.00
	15	-0.05	-0.07	0.24	0.20	0.22	0.06	-2.2	-0.8	12.7	3.4	1.4	0.5	-5.78	-0.29	0.05	1.13	0.01	0.00
	20	-0.01	-0.10	0.34	0.19	0.25	0.08	-2.5	-1.1	12.9	3.7	1.8	0.7	-5.76	-0.30	0.05	1.13	0.01	0.00
13	5	-0.05	-0.02	0.44	0.18	0.13	0.03	-1.7	-0.3	8.7	3.0	0.8	0.3	-8.05	-0.24	0.33	1.10	0.00	0.00
	10	-0.04	-0.04	0.52	0.19	0.15	0.05	-1.8	-0.5	9.5	3.3	1.0	0.5	-8.03	-0.24	0.33	1.11	0.00	0.00
	15	-0.02	-0.06	0.61	0.20	0.17	0.06	-1.8	-0.7	10.2	3.5	1.2	0.6	-7.93	-0.24	0.34	1.11	0.00	0.00
	20	0.01	-0.09	0.65	0.19	0.20	0.08	-1.8	-1.0	10.8	3.7	1.3	0.7	-7.89	-0.25	0.34	1.12	0.00	0.00
14	5	-0.04	-0.02	0.48	0.19	0.11	0.03	-1.7	-0.4	8.6	3.1	0.9	0.4	-9.58	-0.12	0.37	1.10	-0.00	0.00
	10	-0.04	-0.04	0.59	0.22	0.13	0.04	-1.7	-0.6	9.3	3.3	1.1	0.5	-9.50	-0.13	0.38	1.10	-0.00	0.00
	15	-0.01	-0.07	0.65	0.22	0.16	0.06	-1.6	-0.8	10.0	3.5	1.3	0.7	-9.30	-0.15	0.38	1.11	-0.00	0.00
	20	0.03	-0.10	0.75	0.22	0.18	0.08	-1.6	-1.2	10.5	3.6	1.5	0.8	-9.11	-0.16	0.39	1.11	-0.01	0.00
15	5	-0.03	-0.02	0.28	0.20	0.10	0.03	-1.4	-0.3	6.8	2.9	0.8	0.4	-6.94	-0.33	0.18	1.09	0.01	0.00
	10	-0.01	-0.04	0.33	0.21	0.12	0.04	-1.4	-0.6	7.1	3.0	1.0	0.6	-6.73	-0.35	0.19	1.10	0.00	0.00
	15	0.02	-0.06	0.37	0.21	0.14	0.06	-1.2	-0.8	7.3	3.0	1.3	0.7	-6.44	-0.38	0.19	1.10	0.00	0.00
	20	0.07	-0.10	0.38	0.20	0.17	0.08	-1.0	-1.2	7.2	3.0	1.6	0.9	-6.33	-0.40	0.18	1.11	0.00	0.00
16	5	-0.07	-0.01	0.67	0.19	0.23	0.01	-1.3	-0.3	14.7	2.5	1.0	0.2	-3.15	-0.52	0.09	1.14	0.01	0.00
	10	-0.03	-0.03	0.90	0.18	0.25	0.03	-1.5	-0.5	16.0	2.7	1.2	0.3	-2.82	-0.56	0.10	1.14	0.01	0.00
	15	0.01	-0.06	1.05	0.18	0.27	0.05	-1.8	-0.7	17.0	3.0	1.4	0.4	-2.87	-0.57	0.10	1.14	0.01	0.00
	20	0.04	-0.09	1.27	0.18	0.29	0.06	-2.2	-1.1	17.4	3.1	1.7	0.5	-3.09	-0.56	0.11	1.15	0.01	0.00
17	5	-0.08	-0.01	0.79	0.16	0.19	0.01	-1.0	-0.2	12.6	2.0	1.0	0.2	-7.55	-0.28	0.16	1.13	0.00	0.00
	10	-0.06	-0.03	1.05	0.17	0.20	0.02	-1.0	-0.4	13.5	2.2	1.2	0.3	-6.97	-0.34	0.18	1.14	-0.00	0.00
	15	-0.04	-0.05	1.30	0.17	0.21	0.04	-1.1	-0.6	14.2	2.3	1.4	0.4	-7.44	-0.32	0.19	1.14	-0.00	0.00
	20	-0.02	-0.08	1.53	0.18	0.22	0.05	-1.2	-1.0	14.6	2.4	1.7	0.5	-7.82	-0.30	0.20	1.14	-0.00	0.00
18	5	-0.09	-0.01	0.74	0.18	0.11	0.01	-1.0	-0.2	9.2	1.9	0.9	0.2	-11.31	0.04	0.37	1.10	-0.01	0.00
	10	-0.08	-0.02	0.88	0.20	0.13	0.02	-1.0	-0.3	9.7	2.0	1.1	0.3	-11.11	0.02	0.38	1.11	-0.01	0.00
	15	-0.08	-0.04	1.03	0.21	0.14	0.03	-1.0	-0.5	10.1	2.1	1.3	0.4	-11.29	0.04	0.39	1.11	-0.01	0.00
	20	-0.06	-0.05	1.22	0.21	0.15	0.04	-0.9	-0.7	10.4	2.1	1.4	0.4	-11.48	0.05	0.41	1.12	-0.01	0.00

TABLE A(III)-18 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.10	-0.02	1.37	0.21	0.07	0.02	-1.5	-0.3	9.1	2.5	0.9	0.3	-13.58	0.27	0.39	1.10	-0.01	0.00
	10	-0.10	-0.03	1.56	0.23	0.07	0.03	-1.5	-0.5	9.7	2.6	1.1	0.4	-14.07	0.31	0.41	1.10	-0.02	0.00
	15	-0.10	-0.05	1.69	0.24	0.08	0.04	-1.4	-0.8	10.2	2.7	1.3	0.5	-14.41	0.34	0.43	1.11	-0.02	0.00
	20	-0.10	-0.08	1.76	0.26	0.09	0.06	-1.2	-1.1	10.6	2.7	1.5	0.6	-14.53	0.35	0.44	1.12	-0.02	0.00
20	5	-0.03	-0.02	0.73	0.20	0.11	0.03	-1.6	-0.4	9.1	3.0	0.9	0.4	-7.64	-0.19	0.24	1.11	-0.00	0.00
	10	-0.02	-0.04	0.83	0.21	0.12	0.04	-1.7	-0.6	9.9	3.2	1.1	0.5	-7.49	-0.20	0.24	1.11	-0.00	0.00
	15	0.02	-0.07	0.92	0.22	0.14	0.06	-1.7	-0.9	10.5	3.4	1.3	0.6	-7.24	-0.23	0.25	1.12	-0.00	0.00
	20	0.05	-0.10	1.02	0.22	0.16	0.08	-1.8	-1.2	11.0	3.6	1.6	0.8	-7.23	-0.23	0.25	1.12	-0.00	0.00
21	5	-0.04	-0.02	0.58	0.20	0.10	0.03	-1.5	-0.4	7.7	2.9	0.8	0.4	-7.30	-0.13	0.21	1.10	-0.00	0.00
	10	-0.03	-0.04	0.64	0.21	0.11	0.04	-1.5	-0.6	8.2	3.0	1.1	0.6	-7.28	-0.13	0.21	1.10	-0.00	0.00
	15	-0.01	-0.07	0.68	0.22	0.13	0.06	-1.4	-0.9	8.6	3.1	1.4	0.7	-7.09	-0.15	0.21	1.11	-0.00	0.00
	20	0.02	-0.10	0.75	0.22	0.15	0.08	-1.2	-1.3	8.5	3.2	1.7	0.9	-6.95	-0.16	0.21	1.11	-0.00	0.00
22	5	-0.06	-0.01	0.91	0.13	0.15	0.01	-0.7	-0.1	11.3	1.4	0.8	0.1	-6.05	-0.35	0.13	1.13	0.00	0.00
	10	-0.05	-0.02	1.14	0.13	0.15	0.01	-0.6	-0.3	11.9	1.5	1.0	0.2	-5.71	-0.39	0.14	1.13	0.00	0.00
	15	-0.04	-0.03	1.29	0.14	0.16	0.02	-0.6	-0.4	12.3	1.5	1.1	0.2	-5.80	-0.38	0.14	1.13	0.00	0.00
	20	-0.03	-0.04	1.50	0.13	0.17	0.03	-0.7	-0.6	12.5	1.6	1.2	0.3	-6.00	-0.38	0.15	1.14	0.00	0.00
23	5	0.01	-0.01	0.60	0.04	0.15	0.01	-0.3	-0.2	8.5	0.9	0.9	0.2	-4.09	-0.38	0.13	1.13	0.00	0.00
	10	0.02	-0.02	0.68	0.03	0.16	0.02	-0.2	-0.3	8.7	0.9	1.0	0.2	-3.91	-0.41	0.13	1.13	0.00	0.00
	15	0.04	-0.03	0.75	0.03	0.16	0.02	-0.2	-0.4	8.8	0.9	1.2	0.2	-3.97	-0.42	0.13	1.13	0.00	0.00
	20	0.06	-0.04	0.82	0.02	0.17	0.03	-0.1	-0.6	9.0	0.9	1.2	0.3	-4.06	-0.42	0.14	1.13	0.00	0.00
24	5	-0.06	-0.01	0.91	0.12	0.17	0.01	-0.8	-0.2	11.7	1.6	1.0	0.2	-8.30	-0.20	0.14	1.13	0.00	0.00
	10	-0.04	-0.03	1.12	0.12	0.18	0.02	-0.8	-0.4	12.4	1.7	1.2	0.3	-7.80	-0.27	0.16	1.13	0.00	0.00
	15	-0.01	-0.05	1.28	0.11	0.19	0.03	-0.9	-0.6	12.8	1.8	1.4	0.3	-8.02	-0.26	0.17	1.14	-0.00	0.00
	20	0.01	-0.07	1.43	0.11	0.20	0.04	-0.9	-0.9	13.1	1.8	1.5	0.4	-8.23	-0.25	0.17	1.14	-0.00	0.00
25	5	-0.07	-0.01	0.62	0.20	0.12	0.01	-1.1	-0.2	9.3	2.1	0.9	0.2	-12.20	0.02	0.15	1.10	0.00	0.00
	10	-0.08	-0.02	0.69	0.22	0.14	0.02	-1.0	-0.4	10.0	2.2	1.1	0.3	-12.43	0.04	0.15	1.11	0.00	0.00
	15	-0.08	-0.04	0.78	0.24	0.15	0.03	-0.9	-0.6	10.3	2.3	1.4	0.4	-12.74	0.05	0.15	1.11	0.00	0.00
	20	-0.08	-0.06	0.87	0.25	0.17	0.05	-0.7	-0.9	10.6	2.3	1.6	0.6	-13.09	0.08	0.15	1.12	0.00	0.00
26	5	-0.12	-0.02	0.37	0.20	0.10	0.02	-1.6	-0.3	8.1	2.9	0.9	0.4	-15.68	0.23	0.13	1.08	0.00	0.01
	10	-0.14	-0.03	0.42	0.23	0.11	0.04	-1.7	-0.6	8.5	3.0	1.3	0.6	-15.53	0.22	0.14	1.09	0.00	0.00
	15	-0.13	-0.06	0.46	0.24	0.13	0.05	-1.4	-1.0	8.5	2.9	1.6	0.8	-15.85	0.23	0.14	1.10	0.00	0.01
	20	-0.12	-0.09	0.48	0.26	0.16	0.07	-1.1	-1.5	8.3	2.9	2.0	1.0	-16.05	0.24	0.14	1.10	0.00	0.00
27	5	-0.13	-0.03	0.29	0.27	0.12	0.04	-2.1	-0.5	9.2	4.2	1.1	0.6	-12.65	-0.15	0.15	1.11	0.01	0.00
	10	-0.14	-0.05	0.34	0.31	0.14	0.06	-2.0	-1.0	9.5	4.3	1.6	1.0	-12.56	-0.17	0.15	1.11	0.01	0.00
	15	-0.12	-0.10	0.36	0.33	0.18	0.09	-1.7	-1.8	8.5	4.2	2.4	1.4	-12.15	-0.22	0.14	1.12	0.01	0.00
	20	-0.07	-0.16	0.44	0.34	0.23	0.12	-1.2	-2.8	6.7	3.8	3.7	1.9	-12.35	-0.22	0.14	1.13	0.01	0.00

TABLE A(III)-19. SPRING PLOW CORN (C AND D SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.79	0.09	-1.73	48.72	10	5	2.56	-1.25	-2.48	55.97	19	5	3.90	-5.45	-3.87	73.58
	10	1.70	0.16	-1.58	36.92		10	2.49	-1.22	-2.22	41.53		10	3.90	-5.66	-3.81	66.58
	15	1.62	0.07	-1.47	28.26		15	2.35	-1.17	-2.03	32.51		15	3.86	-5.77	-3.73	61.62
	20	1.53	0.08	-1.37	20.76		20	2.26	-1.12	-1.87	25.07		20	3.82	-5.91	-3.69	57.66
2	5	2.68	-2.31	-2.65	56.37	11	5	2.95	-0.61	-2.90	63.57	20	5	3.74	-2.75	-3.71	71.48
	10	2.61	-2.19	-2.51	46.05		10	2.86	-0.54	-2.66	50.91		10	3.74	-2.92	-3.63	62.94
	15	2.53	-2.24	-2.40	38.65		15	2.81	-0.67	-2.49	42.88		15	3.72	-3.05	-3.54	57.14
	20	2.45	-2.20	-2.31	33.18		20	2.74	-0.70	-2.36	36.38		20	3.67	-3.11	-3.42	52.25
3	5	3.45	-1.85	-3.45	69.93	12	5	3.31	-1.31	-3.28	68.42	21	5	3.98	-2.62	-3.95	72.46
	10	3.49	-2.13	-3.48	64.45		10	3.37	-1.59	-3.28	60.16		10	4.00	-2.85	-3.91	64.26
	15	3.48	-2.28	-3.48	61.32		15	3.39	-1.80	-3.24	54.51		15	3.98	-3.00	-3.84	58.61
	20	3.47	-2.48	-3.47	58.77		20	3.37	-2.04	-3.16	49.90		20	3.93	-3.06	-3.77	54.22
4	5	2.91	-1.85	-2.88	61.22	13	5	3.82	0.31	-3.78	71.41	22	5	3.50	-3.59	-3.50	73.94
	10	2.94	-2.21	-2.84	51.88		10	3.81	0.29	-3.67	62.77		10	3.52	-3.85	-3.51	68.51
	15	2.90	-2.42	-2.74	45.32		15	3.77	0.19	-3.52	56.90		15	3.52	-3.95	-3.51	65.15
	20	2.86	-2.60	-2.74	40.36		20	3.74	0.05	-3.41	52.22		20	3.51	-4.13	-3.50	62.43
5	5	3.23	-3.09	-3.21	65.68	14	5	3.89	-1.26	-3.85	71.28	23	5	4.56	-4.17	-4.55	81.77
	10	3.25	-3.26	-3.18	57.98		10	3.89	-1.42	-3.72	62.46		10	4.58	-4.32	-4.55	77.41
	15	3.24	-3.50	-3.17	52.89		15	3.86	-1.55	-3.61	56.66		15	4.59	-4.45	-4.58	74.64
	20	3.23	-3.63	-3.15	48.68		20	3.80	-1.67	-3.49	52.01		20	4.58	-4.55	-4.58	72.31
6	5	1.80	-1.19	-1.70	45.32	15	5	3.92	-0.24	-3.90	69.60	24	5	3.68	-4.32	-3.67	73.48
	10	1.73	-1.41	-1.48	31.39		10	3.95	-0.54	-3.88	61.85		10	3.69	-4.53	-3.65	67.24
	15	1.63	-1.35	-1.27	22.69		15	3.95	-0.75	-3.87	57.16		15	3.68	-4.68	-3.65	63.37
	20	1.54	-1.34	-1.16	16.36		20	3.93	-0.87	-3.86	53.56		20	3.65	-4.76	-3.64	60.23
7	5	2.38	-2.29	-2.32	54.16	16	5	3.14	-2.07	-3.11	67.93	25	5	3.88	-4.83	-3.86	76.01
	10	2.43	-2.69	-2.20	41.13		10	3.12	-2.28	-3.04	60.65		10	3.90	-4.94	-3.85	68.60
	15	2.38	-2.89	-1.98	32.40		15	3.09	-2.39	-2.98	55.31		15	3.90	-5.15	-3.85	63.60
	20	2.32	-2.94	-1.81	25.51		20	3.08	-2.59	-2.99	51.49		20	3.88	-5.30	-3.83	59.65
8	5	3.31	-3.14	-3.27	67.44	17	5	3.42	-3.81	-3.41	70.94	26	5	3.82	-4.16	-3.80	71.86
	10	3.38	-3.48	-3.28	59.57		10	3.44	-4.05	-3.39	64.01		10	3.89	-4.56	-3.84	63.70
	15	3.39	-3.74	-3.25	54.26		15	3.42	-4.23	-3.36	59.18		15	3.92	-4.87	-3.87	59.10
	20	3.38	-4.01	-3.24	50.23		20	3.41	-4.39	-3.34	55.01		20	3.91	-4.95	-3.87	55.52
9	5	2.16	-2.75	-2.04	46.74	18	5	3.99	-4.95	-3.99	77.06	27	5	3.64	-3.49	-3.62	65.81
	10	2.02	-2.71	-1.66	31.08		10	3.98	-5.04	-3.94	70.52		10	3.69	-3.78	-3.64	56.93
	15	1.93	-2.68	-1.53	22.67		15	3.93	-5.09	-3.88	65.77		15	3.73	-4.15	-3.63	51.38
	20	1.82	-2.57	-1.32	16.02		20	3.90	-5.20	-3.85	61.84		20	3.75	-4.40	-3.62	47.15

TABLE A(III)-20. SPRING PLOW CORN, SPRING FERTILIZATION (C AND D SOILS)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	0.25	-0.15	7.79	0.34	-0.30	0.06	-13.5	-0.7	40.3	9.0	2.2	0.5	0.12	-0.20	1.13	1.16	-0.04	0.00
	10	0.41	-0.28	8.00	0.29	-0.04	0.13	-16.8	-1.1	49.8	11.2	3.5	0.8	0.15	-0.20	1.13	1.16	-0.05	0.00
	15	0.49	-0.40	7.91	0.26	0.34	0.21	-20.4	-2.0	60.4	13.6	6.1	1.4	0.14	-0.20	1.14	1.17	-0.05	0.00
	20	0.50	-0.55	8.07	0.27	0.80	0.31	-24.7	-4.0	72.5	16.4	12.4	2.8	0.12	-0.20	1.14	1.17	-0.05	0.00
2	5	0.12	-0.12	6.05	0.24	-0.26	0.04	-9.8	-0.9	29.4	5.5	2.9	0.5	0.12	-0.24	0.92	1.16	-0.03	0.00
	10	0.12	-0.20	6.49	0.26	-0.09	0.08	-11.2	-1.4	33.6	6.3	4.4	0.8	0.16	-0.24	0.92	1.16	-0.03	0.00
	15	0.08	-0.27	6.69	0.28	0.14	0.12	-12.3	-2.1	36.9	6.9	6.6	1.2	0.24	-0.25	0.90	1.17	-0.03	0.00
	20	-0.02	-0.34	6.94	0.33	0.39	0.16	-12.8	-3.1	38.1	7.1	9.6	1.8	0.21	-0.25	0.90	1.17	-0.03	0.00
3	5	0.01	-0.07	4.32	0.14	-0.23	0.02	-5.8	-0.9	14.1	2.2	1.7	0.2	-0.36	-0.41	0.75	1.15	-0.02	0.00
	10	0.10	-0.12	4.44	0.13	-0.16	0.03	-6.8	-1.2	15.0	2.4	2.1	0.3	-0.23	-0.44	0.74	1.15	-0.01	0.00
	15	0.16	-0.18	4.45	0.13	-0.08	0.04	-7.7	-1.5	15.7	2.5	2.4	0.4	-0.23	-0.45	0.73	1.15	-0.01	0.00
	20	0.22	-0.23	4.44	0.12	0.01	0.05	-8.5	-1.6	16.4	2.6	2.5	0.4	-0.17	-0.46	0.72	1.15	-0.01	0.00
4	5	0.05	-0.10	5.35	0.25	-0.26	0.03	-9.2	-1.2	19.7	4.4	2.0	0.4	-0.49	-0.50	0.91	1.15	-0.02	0.00
	10	0.22	-0.20	5.33	0.22	-0.13	0.06	-11.6	-2.0	22.5	5.0	3.1	0.7	-0.30	-0.53	0.90	1.16	-0.02	0.00
	15	0.38	-0.31	5.24	0.19	0.02	0.10	-14.0	-2.7	24.9	5.5	4.2	0.9	-0.25	-0.54	0.90	1.16	-0.02	0.00
	20	0.54	-0.44	5.14	0.16	0.22	0.14	-15.2	-3.7	25.6	5.6	5.9	1.3	-0.18	-0.55	0.90	1.16	-0.02	0.00
5	5	0.05	-0.09	4.42	0.21	-0.24	0.02	-7.9	-1.1	15.1	3.4	1.7	0.4	-0.66	-0.69	0.73	1.15	-0.01	0.00
	10	0.17	-0.17	4.50	0.20	-0.15	0.05	-9.3	-1.6	16.6	3.7	2.4	0.5	-0.52	-0.72	0.72	1.15	-0.01	0.00
	15	0.28	-0.24	4.35	0.18	-0.04	0.07	-10.4	-2.2	17.5	3.9	3.1	0.7	-0.45	-0.74	0.71	1.15	-0.01	0.00
	20	0.35	-0.33	4.26	0.17	0.10	0.09	-11.4	-2.8	18.2	4.0	3.9	0.9	-0.55	-0.75	0.71	1.16	-0.01	0.00
6	5	0.11	-0.16	9.94	0.36	-0.53	0.06	-21.2	-1.7	40.2	10.3	2.6	0.7	0.08	-0.66	1.10	1.17	-0.02	-0.00
	10	0.38	-0.35	10.54	0.34	-0.35	0.13	-32.8	-3.5	55.5	14.0	5.1	1.3	0.87	-0.73	1.09	1.17	-0.02	0.00
	15	0.41	-0.62	11.17	0.42	-0.02	0.21	-44.9	-6.5	70.8	17.8	9.3	2.3	1.02	-0.73	1.09	1.17	-0.02	0.00
	20	0.11	-0.95	12.22	0.61	0.40	0.32	-56.9	-11.5	86.1	21.6	16.7	4.1	1.20	-0.74	1.09	1.17	-0.02	0.00
7	5	0.01	-0.11	7.49	0.38	-0.43	0.04	-11.9	-1.3	23.0	7.0	2.0	0.6	-0.66	-0.70	1.12	1.16	-0.02	-0.00
	10	0.17	-0.23	7.66	0.36	-0.31	0.09	-16.3	-2.6	28.8	8.7	3.8	1.1	-0.25	-0.75	1.11	1.16	-0.02	0.00
	15	0.31	-0.40	8.06	0.38	-0.14	0.15	-20.9	-4.3	34.3	10.3	6.0	1.7	0.06	-0.79	1.10	1.17	-0.02	0.00
	20	0.33	-0.61	8.48	0.44	0.14	0.23	-24.9	-7.1	38.0	11.2	10.2	2.9	0.13	-0.80	1.09	1.17	-0.02	0.00
8	5	-0.10	-0.07	3.71	0.26	-0.20	0.02	-7.4	-0.9	12.1	3.3	1.3	0.3	-3.57	-0.52	0.77	1.13	-0.01	0.00
	10	-0.04	-0.13	3.71	0.26	-0.12	0.04	-8.3	-1.4	13.2	3.6	1.9	0.5	-3.52	-0.53	0.76	1.14	-0.01	0.00
	15	0.04	-0.20	3.59	0.25	-0.02	0.06	-9.0	-1.8	14.0	3.8	2.4	0.6	-3.53	-0.54	0.76	1.14	-0.01	0.00
	20	0.09	-0.27	3.48	0.25	0.09	0.08	-9.5	-2.3	14.5	3.9	3.0	0.8	-3.67	-0.54	0.76	1.14	-0.01	0.00
9	5	-0.18	-0.20	6.90	0.76	-0.31	0.06	-26.9	-2.7	35.1	13.4	3.1	1.1	-5.31	-1.28	0.71	1.17	0.03	-0.00
	10	-0.74	-0.35	7.62	1.29	-0.17	0.09	-41.7	-5.5	50.7	18.8	6.2	2.3	-5.08	-1.29	0.70	1.17	0.03	-0.00
	15	-2.57	-0.52	9.48	2.28	0.05	0.13	-53.2	-10.4	62.5	23.0	11.8	4.2	-5.42	-1.29	0.70	1.17	0.03	0.00
	20	-5.24	-0.84	12.34	3.51	0.42	0.24	-74.5	-12.4	84.4	30.9	14.6	5.0	-5.57	-1.33	0.71	1.17	0.03	0.00

TABLE A(III)-20 (CONT)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
10	5	-0.01	-0.14	4.89	0.50	-0.22	0.06	-16.8	-1.7	22.0	10.0	2.0	0.9	-4.69	-1.16	0.70	1.16	0.02	-0.00
	10	0.02	-0.27	4.83	0.64	-0.09	0.11	-23.2	-3.5	28.5	12.7	3.8	1.6	-4.67	-1.14	0.70	1.16	0.02	0.00
	15	-0.16	-0.44	4.85	0.87	0.12	0.17	-28.3	-6.2	33.6	14.7	6.6	2.8	-4.67	-1.14	0.69	1.17	0.03	0.00
	20	-0.59	-0.70	5.01	1.17	0.44	0.27	-29.9	-11.9	35.0	15.1	12.7	5.3	-4.92	-1.12	0.70	1.17	0.03	0.00
11	5	0.04	-0.10	3.53	0.35	-0.17	0.05	-10.1	-1.1	13.7	6.9	1.3	0.6	-2.04	-1.14	0.66	1.15	0.01	0.00
	10	0.13	-0.18	3.55	0.39	-0.10	0.08	-13.2	-1.9	16.8	8.3	2.1	1.0	-1.87	-1.13	0.66	1.15	0.01	0.00
	15	0.26	-0.28	3.39	0.40	0.03	0.13	-15.7	-2.9	19.3	9.4	3.1	1.4	-1.54	-1.16	0.65	1.16	0.02	0.00
	20	0.38	-0.43	3.26	0.42	0.20	0.19	-18.0	-4.2	21.5	10.2	4.4	2.1	-1.48	-1.17	0.64	1.16	0.02	0.00
12	5	0.00	-0.06	3.78	0.21	-0.20	0.03	-5.2	-0.7	10.6	3.5	1.2	0.4	-1.87	-0.58	0.90	1.14	-0.01	0.00
	10	0.06	-0.10	3.69	0.20	-0.14	0.05	-5.9	-1.2	11.5	3.8	1.7	0.5	-1.97	-0.57	0.89	1.14	-0.01	0.00
	15	0.13	-0.16	3.65	0.19	-0.06	0.07	-6.7	-1.6	12.4	4.1	2.2	0.7	-1.97	-0.58	0.89	1.14	-0.01	0.00
	20	0.21	-0.22	3.59	0.16	0.03	0.09	-7.7	-2.0	13.3	4.3	2.7	0.8	-1.86	-0.60	0.88	1.14	-0.00	0.00
13	5	-0.00	-0.06	2.01	0.18	-0.08	0.04	-4.6	-0.8	7.8	3.5	1.1	0.5	-3.89	-0.55	0.67	1.12	0.00	0.00
	10	0.03	-0.09	2.01	0.18	-0.04	0.05	-5.6	-1.3	8.7	3.8	1.6	0.6	-3.88	-0.55	0.67	1.12	0.00	0.00
	15	0.10	-0.15	1.94	0.17	0.03	0.07	-6.4	-1.6	9.5	4.1	1.9	0.8	-3.79	-0.55	0.67	1.12	0.00	0.00
	20	0.18	-0.21	1.86	0.15	0.11	0.10	-7.1	-1.8	10.2	4.3	2.2	0.9	-3.69	-0.56	0.67	1.13	0.00	0.00
14	5	-0.02	-0.05	2.12	0.22	-0.11	0.03	-4.9	-0.9	7.6	3.6	1.2	0.5	-5.03	-0.49	0.65	1.11	-0.00	0.00
	10	0.02	-0.10	2.15	0.23	-0.06	0.05	-5.7	-1.3	8.4	3.9	1.6	0.7	-4.92	-0.50	0.65	1.11	-0.00	0.00
	15	0.09	-0.16	2.09	0.22	0.02	0.08	-6.4	-1.7	9.0	4.1	2.0	0.8	-4.76	-0.51	0.64	1.12	-0.00	0.00
	20	0.17	-0.22	2.03	0.21	0.09	0.10	-7.0	-2.0	9.6	4.3	2.3	1.0	-4.55	-0.53	0.63	1.12	-0.00	0.00
15	5	0.01	-0.05	1.88	0.23	-0.09	0.03	-3.4	-0.8	6.0	3.2	1.1	0.5	-3.74	-0.56	0.68	1.10	0.00	0.00
	10	0.06	-0.09	1.93	0.24	-0.05	0.05	-3.8	-1.2	6.4	3.3	1.5	0.7	-3.52	-0.58	0.67	1.11	0.01	0.00
	15	0.12	-0.13	1.93	0.24	0.00	0.07	-3.8	-1.6	6.4	3.3	2.0	0.9	-3.27	-0.61	0.66	1.11	0.01	0.00
	20	0.19	-0.18	1.89	0.23	0.07	0.09	-3.9	-2.0	6.3	3.2	2.4	1.1	-3.18	-0.63	0.66	1.12	0.01	0.00
16	5	0.02	-0.07	5.08	0.28	-0.31	0.02	-7.0	-0.9	13.7	3.3	1.4	0.3	-0.94	-0.67	0.89	1.14	-0.03	0.00
	10	0.12	-0.13	5.19	0.27	-0.25	0.03	-8.9	-1.2	15.4	3.7	1.8	0.4	-0.71	-0.70	0.89	1.14	-0.02	0.00
	15	0.22	-0.21	5.18	0.26	-0.15	0.05	-10.6	-1.5	16.8	4.0	2.1	0.5	-0.73	-0.71	0.88	1.15	-0.02	0.00
	20	0.28	-0.28	5.10	0.26	-0.04	0.07	-11.7	-1.8	17.7	4.2	2.5	0.6	-0.81	-0.72	0.87	1.15	-0.02	0.00
17	5	-0.06	-0.07	4.56	0.30	-0.29	0.01	-6.5	-0.8	10.8	2.9	1.2	0.3	-3.04	-0.66	0.83	1.13	-0.02	0.00
	10	0.03	-0.13	4.84	0.31	-0.25	0.03	-7.6	-1.2	11.8	3.1	1.5	0.4	-2.58	-0.71	0.82	1.14	-0.02	0.00
	15	0.08	-0.20	4.70	0.31	-0.16	0.05	-8.5	-1.4	12.7	3.3	1.8	0.5	-2.79	-0.71	0.81	1.14	-0.02	0.00
	20	0.10	-0.26	4.68	0.31	-0.06	0.06	-9.4	-1.8	13.4	3.5	2.2	0.6	-3.00	-0.71	0.81	1.14	-0.02	0.00
18	5	-0.11	-0.05	3.51	0.31	-0.23	0.01	-4.5	-0.7	7.4	2.5	1.0	0.3	-6.30	-0.41	0.92	1.11	-0.03	0.00
	10	-0.07	-0.10	3.85	0.34	-0.21	0.02	-5.2	-1.0	7.9	2.7	1.2	0.4	-5.97	-0.44	0.91	1.11	-0.03	0.00
	15	-0.06	-0.14	3.86	0.36	-0.16	0.03	-5.9	-1.2	8.5	2.8	1.4	0.4	-6.06	-0.43	0.91	1.11	-0.03	0.00
	20	-0.04	-0.18	3.87	0.37	-0.10	0.05	-6.5	-1.5	9.0	2.9	1.7	0.5	-6.13	-0.43	0.90	1.12	-0.03	0.00

TABLE A(III) -20 (CONT)

REGION	AW		DISSOLVED N IN RUNOFF					DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
		A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.16	-0.05	2.73	0.35	-0.16	0.01	-5.2	-0.8	7.8	3.1	1.1	0.4	-8.69	-0.18	0.71	1.11	-0.01	0.00
	10	-0.17	-0.10	2.75	0.38	-0.11	0.03	-5.9	-1.2	8.4	3.3	1.4	0.5	-8.97	-0.16	0.70	1.11	-0.01	0.00
	15	-0.18	-0.14	2.62	0.39	-0.03	0.05	-6.7	-1.4	9.0	3.4	1.6	0.6	-9.26	-0.14	0.70	1.11	-0.01	0.00
	20	-0.20	-0.19	2.59	0.41	0.04	0.06	-7.2	-1.7	9.5	3.5	1.9	0.7	-9.33	-0.14	0.69	1.12	-0.01	0.00
20	5	-0.01	-0.05	3.07	0.26	-0.18	0.02	-4.8	-0.8	8.2	3.5	1.1	0.4	-3.59	-0.52	0.71	1.12	-0.01	0.00
	10	0.06	-0.10	3.00	0.26	-0.12	0.05	-5.7	-1.3	9.1	3.8	1.6	0.6	-3.48	-0.53	0.70	1.12	-0.01	0.00
	15	0.13	-0.16	2.95	0.25	-0.05	0.07	-6.4	-1.6	9.8	4.0	2.0	0.8	-3.28	-0.55	0.68	1.12	-0.01	0.00
	20	0.19	-0.22	2.90	0.25	0.03	0.09	-7.1	-2.0	10.5	4.2	2.3	0.9	-3.23	-0.56	0.67	1.13	-0.00	0.00
21	5	-0.02	-0.05	2.49	0.26	-0.14	0.03	-3.9	-0.8	7.0	3.3	1.1	0.5	-4.08	-0.40	0.71	1.11	-0.01	0.00
	10	0.02	-0.09	2.40	0.26	-0.08	0.05	-4.2	-1.2	7.4	3.4	1.6	0.7	-4.05	-0.40	0.71	1.11	-0.01	0.00
	15	0.06	-0.14	2.37	0.25	-0.02	0.07	-4.4	-1.7	7.7	3.5	2.0	0.8	-3.90	-0.42	0.70	1.11	-0.00	0.00
	20	0.11	-0.19	2.35	0.25	0.06	0.09	-4.7	-2.1	8.0	3.6	2.5	1.0	-3.78	-0.43	0.69	1.12	-0.00	0.00
22	5	-0.05	-0.06	4.38	0.23	-0.28	0.01	-5.3	-0.6	9.9	2.2	1.0	0.2	-2.26	-0.66	0.87	1.13	-0.02	0.00
	10	0.02	-0.10	4.60	0.24	-0.24	0.02	-5.9	-0.9	10.6	2.3	1.3	0.3	-1.99	-0.69	0.86	1.13	-0.02	0.00
	15	0.05	-0.14	4.65	0.24	-0.19	0.03	-6.4	-1.1	11.1	2.4	1.4	0.3	-2.04	-0.69	0.86	1.14	-0.02	0.00
	20	0.10	-0.19	4.61	0.24	-0.12	0.04	-7.0	-1.2	11.6	2.5	1.6	0.3	-2.12	-0.70	0.86	1.14	-0.02	0.00
23	5	0.00	-0.04	2.32	0.12	-0.14	0.01	-3.6	-0.7	6.9	1.5	1.2	0.2	-2.80	-0.48	0.49	1.12	-0.00	0.00
	10	0.04	-0.08	2.43	0.12	-0.11	0.02	-4.2	-0.9	7.2	1.5	1.4	0.3	-2.64	-0.51	0.48	1.12	-0.00	0.00
	15	0.06	-0.12	2.33	0.12	-0.05	0.03	-4.7	-1.1	7.5	1.6	1.5	0.3	-2.71	-0.52	0.47	1.12	-0.00	0.00
	20	0.08	-0.15	2.28	0.12	0.01	0.03	-5.2	-1.2	7.8	1.6	1.6	0.3	-2.80	-0.52	0.47	1.13	0.00	0.00
24	5	-0.08	-0.06	4.16	0.26	-0.26	0.01	-5.5	-0.8	9.8	2.4	1.2	0.3	-4.02	-0.57	0.84	1.13	-0.02	0.00
	10	-0.01	-0.12	4.50	0.27	-0.24	0.02	-6.5	-1.1	10.6	2.6	1.5	0.3	-3.54	-0.63	0.83	1.13	-0.02	0.00
	15	0.04	-0.17	4.42	0.27	-0.16	0.04	-7.4	-1.4	11.2	2.7	1.7	0.4	-3.65	-0.64	0.82	1.14	-0.02	0.00
	20	0.07	-0.23	4.39	0.27	-0.08	0.05	-8.2	-1.5	11.8	2.8	1.9	0.5	-3.81	-0.64	0.82	1.14	-0.02	0.00
25	5	-0.09	-0.06	3.70	0.34	-0.24	0.01	-5.3	-0.7	8.1	2.7	1.0	0.3	-6.18	-0.52	0.82	1.11	-0.02	0.00
	10	-0.10	-0.10	3.75	0.36	-0.20	0.02	-5.8	-1.0	8.7	2.9	1.4	0.4	-6.38	-0.50	0.82	1.12	-0.01	0.00
	15	-0.11	-0.14	3.73	0.37	-0.14	0.04	-6.2	-1.4	9.1	3.0	1.7	0.5	-6.62	-0.50	0.82	1.12	-0.01	0.00
	20	-0.12	-0.18	3.75	0.39	-0.07	0.05	-6.5	-1.7	9.4	3.1	2.0	0.6	-6.89	-0.48	0.83	1.12	-0.01	0.00
26	5	-0.16	-0.05	2.88	0.33	-0.17	0.02	-4.2	-0.7	7.4	3.3	1.0	0.4	-10.50	-0.23	1.01	1.10	-0.01	0.00
	10	-0.17	-0.08	2.92	0.35	-0.13	0.04	-4.8	-1.2	7.6	3.4	1.5	0.6	-10.40	-0.24	1.00	1.11	-0.01	0.00
	15	-0.16	-0.13	2.98	0.38	-0.07	0.05	-4.8	-1.7	7.6	3.4	2.0	0.8	-10.54	-0.24	0.99	1.11	-0.01	0.00
	20	-0.17	-0.18	2.98	0.40	-0.00	0.07	-4.5	-2.2	7.5	3.3	2.5	1.1	-10.81	-0.23	1.00	1.12	-0.01	0.00
27	5	-0.13	-0.06	3.05	0.39	-0.17	0.03	-4.9	-0.9	8.4	4.6	1.3	0.7	-7.30	-0.61	0.98	1.13	-0.00	0.00
	10	-0.15	-0.11	3.27	0.47	-0.13	0.05	-5.0	-1.8	8.5	4.7	2.3	1.1	-7.10	-0.64	0.97	1.13	0.00	0.00
	15	-0.12	-0.17	3.39	0.54	-0.07	0.08	-4.7	-2.7	8.0	4.4	3.3	1.6	-6.65	-0.69	0.97	1.14	0.00	0.00
	20	-0.09	-0.25	3.42	0.60	0.02	0.12	-4.2	-3.7	6.8	3.7	4.6	2.2	-6.67	-0.71	0.96	1.14	0.00	0.00

TABLE A(III)-21. SPRING PLOW CORN, FALL FERTILIZATION (C AND D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	0.10	-0.07	-0.93	0.36	0.57	0.05	-6.8	-0.7	38.2	8.4	1.9	0.5	0.12	-0.20	-0.01	1.16	0.01	0.00
	10	0.28	-0.18	-0.91	0.30	0.79	0.12	-11.5	-1.4	47.8	10.9	3.4	0.8	0.15	-0.20	-0.01	1.16	0.01	0.00
	15	0.49	-0.33	-0.94	0.26	1.09	0.20	-18.4	-2.2	59.8	13.5	5.9	1.4	0.14	-0.20	-0.01	1.17	0.01	0.00
	20	0.61	-0.53	-0.83	0.27	1.49	0.30	-24.1	-4.0	72.3	16.3	12.2	2.8	0.12	-0.20	-0.02	1.17	0.01	0.00
2	5	0.07	-0.07	0.61	0.25	0.42	0.04	-4.2	-0.9	27.8	5.0	2.4	0.5	0.12	-0.24	-0.01	1.16	0.01	0.00
	10	0.16	-0.14	0.81	0.25	0.54	0.07	-6.3	-1.7	31.4	6.0	4.2	0.8	0.16	-0.24	-0.01	1.16	0.01	0.00
	15	0.23	-0.23	1.01	0.27	0.70	0.12	-9.8	-2.4	35.2	6.7	6.4	1.2	0.24	-0.25	-0.01	1.17	0.01	0.00
	20	0.26	-0.33	1.25	0.32	0.88	0.16	-12.1	-3.2	37.1	7.1	9.4	1.8	0.21	-0.25	-0.01	1.17	0.01	0.00
3	5	-0.03	-0.02	0.19	0.15	0.27	0.01	-1.0	-0.4	15.1	1.6	1.3	0.2	-0.36	-0.41	-0.01	1.15	0.01	0.00
	10	0.02	-0.04	0.34	0.14	0.29	0.02	-1.3	-0.7	15.6	1.7	1.6	0.3	-0.23	-0.44	-0.01	1.15	0.01	0.00
	15	0.07	-0.07	0.49	0.13	0.32	0.03	-1.7	-1.0	15.5	1.8	1.9	0.3	-0.23	-0.45	-0.01	1.15	0.01	0.00
	20	0.12	-0.10	0.64	0.12	0.35	0.04	-2.3	-1.2	15.5	2.0	2.1	0.4	-0.17	-0.46	-0.01	1.15	0.01	0.00
4	5	-0.02	-0.03	-0.43	0.26	0.37	0.02	-2.4	-0.5	20.4	3.6	1.6	0.4	-0.49	-0.50	-0.01	1.15	0.01	0.00
	10	0.06	-0.08	-0.37	0.23	0.44	0.05	-2.9	-1.1	22.5	4.0	2.4	0.6	-0.30	-0.53	-0.01	1.16	0.01	0.00
	15	0.17	-0.13	-0.24	0.20	0.52	0.08	-3.9	-1.9	23.2	4.6	3.5	0.9	-0.25	-0.54	-0.00	1.16	0.01	0.00
	20	0.31	-0.22	-0.08	0.16	0.61	0.12	-4.7	-3.1	21.4	4.9	5.7	1.3	-0.18	-0.55	-0.00	1.16	0.01	0.00
5	5	-0.01	-0.02	-0.01	0.22	0.30	0.01	-1.5	-0.4	16.5	2.6	1.4	0.3	-0.66	-0.69	0.00	1.15	0.01	0.00
	10	0.03	-0.05	0.13	0.21	0.33	0.03	-1.6	-0.8	17.7	2.8	1.9	0.5	-0.52	-0.72	0.01	1.15	0.01	0.00
	15	0.08	-0.08	0.31	0.19	0.37	0.05	-1.6	-1.4	18.3	2.9	2.4	0.7	-0.45	-0.74	0.01	1.15	0.01	0.00
	20	0.16	-0.13	0.49	0.18	0.41	0.07	-1.9	-2.1	17.6	3.0	3.2	0.9	-0.55	-0.75	0.01	1.16	0.01	0.00
6	5	-0.01	-0.07	-0.35	0.38	0.44	0.05	-8.7	-0.9	39.6	8.9	2.1	0.6	0.08	-0.66	-0.01	1.17	0.00	-0.00
	10	0.18	-0.19	0.27	0.36	0.59	0.11	-17.1	-2.5	50.1	12.8	4.5	1.2	0.87	-0.73	-0.01	1.17	0.00	0.00
	15	0.30	-0.38	1.09	0.41	0.79	0.20	-27.2	-5.5	63.5	16.7	8.7	2.2	1.02	-0.73	-0.01	1.17	0.00	0.00
	20	0.20	-0.65	2.11	0.60	1.11	0.30	-38.3	-10.8	77.7	20.4	16.1	4.1	1.20	-0.74	-0.01	1.17	0.00	0.00
7	5	-0.05	-0.05	-0.14	0.39	0.34	0.04	-4.8	-0.7	23.7	6.1	1.6	0.5	-0.66	-0.70	0.00	1.16	0.01	-0.00
	10	0.06	-0.12	0.23	0.37	0.43	0.08	-7.1	-1.8	27.6	7.7	3.1	1.1	-0.25	-0.75	0.00	1.16	0.01	0.00
	15	0.20	-0.24	0.79	0.38	0.51	0.14	-10.6	-3.3	30.7	9.5	5.4	1.7	0.06	-0.79	0.00	1.17	0.01	0.00
	20	0.29	-0.40	1.31	0.44	0.67	0.21	-12.5	-6.6	32.9	10.4	9.9	2.9	0.13	-0.80	0.00	1.17	0.01	0.00
8	5	-0.08	-0.02	0.12	0.26	0.21	0.01	-1.6	-0.4	13.2	2.6	1.2	0.3	-3.57	-0.52	0.05	1.13	0.00	0.00
	10	-0.05	-0.04	0.22	0.26	0.25	0.03	-1.7	-0.7	14.3	2.7	1.6	0.4	-3.52	-0.53	0.05	1.14	0.00	0.00
	15	-0.01	-0.07	0.31	0.25	0.28	0.04	-1.7	-1.1	15.0	2.8	2.0	0.6	-3.53	-0.54	0.05	1.14	0.00	0.00
	20	0.04	-0.11	0.43	0.24	0.31	0.06	-1.6	-1.6	15.2	2.8	2.4	0.8	-3.67	-0.54	0.05	1.14	0.00	0.00
9	5	-0.20	-0.09	2.01	0.76	0.20	0.04	-12.4	-1.7	36.6	11.5	2.6	1.1	-5.31	-1.28	0.08	1.17	0.01	-0.00
	10	-0.49	-0.21	4.77	1.23	0.10	0.07	-26.1	-4.5	46.3	17.3	5.4	2.2	-5.08	-1.29	0.09	1.17	0.01	-0.00
	15	-1.76	-0.40	8.50	2.18	0.04	0.13	-40.6	-9.2	55.7	22.1	11.0	4.1	-5.42	-1.29	0.11	1.17	0.01	0.00
	20	-4.08	-0.70	12.35	3.43	0.24	0.23	-63.6	-10.7	78.2	30.1	13.0	4.8	-5.57	-1.33	0.11	1.17	0.01	0.00

TABLE A(III)-21 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.10	-0.06	0.46	0.52	0.25	0.04	-6.4	-0.9	25.0	8.5	1.8	0.8	-4.69	-1.16	0.09	1.16	0.02	-0.00
	10	-0.06	-0.14	1.20	0.65	0.31	0.09	-10.4	-2.6	29.9	11.1	3.0	1.6	-4.67	-1.14	0.10	1.16	0.02	0.00
	15	-0.05	-0.28	2.07	0.83	0.37	0.15	-15.9	-5.2	31.3	13.5	5.9	2.8	-4.67	-1.14	0.09	1.17	0.02	0.00
	20	-0.20	-0.53	3.02	1.10	0.50	0.26	-18.4	-10.9	30.2	14.3	12.3	5.2	-4.92	-1.12	0.09	1.17	0.02	0.00
11	5	-0.03	-0.04	-0.02	0.36	0.22	0.04	-3.7	-0.5	15.7	6.0	1.2	0.6	-2.04	-1.14	0.05	1.15	0.02	0.00
	10	0.02	-0.08	0.08	0.40	0.26	0.07	-4.8	-1.2	18.5	7.2	1.8	0.9	-1.87	-1.13	0.05	1.15	0.02	0.00
	15	0.12	-0.15	0.25	0.41	0.32	0.11	-6.0	-2.2	20.1	8.2	2.4	1.4	-1.54	-1.16	0.05	1.16	0.02	0.00
	20	0.28	-0.26	0.49	0.42	0.38	0.17	-7.6	-3.6	20.1	9.2	4.0	2.1	-1.48	-1.17	0.05	1.16	0.02	0.00
12	5	-0.02	-0.03	-0.11	0.22	0.19	0.02	-2.1	-0.3	11.4	3.1	1.0	0.3	-1.87	-0.58	0.01	1.14	0.01	0.00
	10	0.01	-0.05	-0.07	0.20	0.21	0.04	-2.2	-0.6	12.4	3.3	1.4	0.5	-1.97	-0.57	0.01	1.14	0.01	0.00
	15	0.05	-0.08	-0.02	0.19	0.24	0.06	-2.1	-1.0	12.9	3.5	1.8	0.7	-1.97	-0.58	0.01	1.14	0.01	0.00
	20	0.12	-0.12	0.06	0.16	0.27	0.08	-2.3	-1.4	12.8	3.7	2.3	0.8	-1.86	-0.60	0.01	1.14	0.01	0.00
13	5	-0.02	-0.03	0.10	0.18	0.15	0.03	-1.7	-0.4	9.0	3.1	0.9	0.4	-3.89	-0.55	0.16	1.12	0.02	0.00
	10	-0.00	-0.04	0.13	0.18	0.17	0.05	-1.7	-0.7	9.8	3.3	1.3	0.6	-3.88	-0.55	0.16	1.12	0.01	0.00
	15	0.04	-0.07	0.17	0.17	0.20	0.07	-1.6	-1.0	10.4	3.5	1.5	0.7	-3.79	-0.55	0.16	1.12	0.01	0.00
	20	0.10	-0.11	0.18	0.15	0.23	0.09	-1.6	-1.3	10.8	3.7	1.8	0.9	-3.69	-0.56	0.16	1.13	0.01	0.00
14	5	-0.03	-0.02	0.16	0.22	0.13	0.03	-1.7	-0.4	8.8	3.1	1.0	0.4	-5.03	-0.49	0.20	1.11	0.01	0.00
	10	-0.00	-0.04	0.21	0.23	0.16	0.04	-1.6	-0.7	9.5	3.3	1.3	0.6	-4.92	-0.50	0.20	1.11	0.01	0.00
	15	0.04	-0.08	0.23	0.22	0.19	0.07	-1.5	-1.1	10.0	3.4	1.6	0.8	-4.76	-0.51	0.20	1.12	0.01	0.00
	20	0.11	-0.11	0.28	0.21	0.23	0.09	-1.3	-1.5	10.3	3.6	1.9	1.0	-4.55	-0.53	0.20	1.12	0.01	0.00
15	5	0.00	-0.03	0.10	0.23	0.11	0.03	-1.4	-0.4	6.9	2.9	0.9	0.5	-3.74	-0.56	0.10	1.10	0.01	0.00
	10	0.03	-0.05	0.12	0.24	0.13	0.04	-1.3	-0.7	7.2	3.0	1.3	0.7	-3.52	-0.58	0.10	1.11	0.01	0.00
	15	0.08	-0.07	0.14	0.24	0.16	0.06	-1.0	-1.1	7.2	2.9	1.6	0.9	-3.27	-0.61	0.10	1.11	0.01	0.00
	20	0.15	-0.11	0.15	0.22	0.19	0.09	-0.6	-1.5	6.7	2.8	2.1	1.1	-3.18	-0.63	0.10	1.12	0.01	0.00
16	5	-0.06	-0.01	0.05	0.29	0.27	0.01	-1.4	-0.3	15.2	2.6	1.1	0.3	-1.01	-0.66	0.03	1.14	0.01	0.00
	10	-0.01	-0.04	0.14	0.28	0.30	0.02	-1.6	-0.6	16.7	2.8	1.4	0.4	-0.78	-0.69	0.03	1.14	0.01	0.00
	15	0.04	-0.06	0.22	0.27	0.33	0.04	-2.0	-0.9	17.8	3.1	1.7	0.5	-0.80	-0.70	0.03	1.15	0.01	0.00
	20	0.09	-0.10	0.35	0.26	0.36	0.06	-2.3	-1.3	18.3	3.3	2.0	0.6	-0.89	-0.71	0.04	1.15	0.01	0.00
17	5	-0.09	-0.01	0.10	0.31	0.24	0.00	-1.0	-0.3	12.9	2.0	1.1	0.2	-3.04	-0.66	0.06	1.13	0.01	0.00
	10	-0.06	-0.03	0.19	0.32	0.27	0.01	-1.0	-0.5	13.8	2.2	1.3	0.3	-2.58	-0.71	0.07	1.14	0.01	0.00
	15	-0.03	-0.05	0.31	0.31	0.30	0.03	-1.1	-0.7	14.4	2.3	1.6	0.4	-2.79	-0.71	0.07	1.14	0.01	0.00
	20	0.02	-0.08	0.44	0.31	0.32	0.04	-1.1	-1.1	14.8	2.4	1.9	0.5	-3.00	-0.71	0.08	1.14	0.01	0.00
18	5	-0.11	-0.01	0.27	0.32	0.15	0.00	-1.0	-0.2	9.3	1.9	1.0	0.2	-6.30	-0.41	0.20	1.11	0.01	0.00
	10	-0.09	-0.02	0.32	0.34	0.17	0.01	-1.0	-0.4	9.8	2.0	1.2	0.3	-5.97	-0.44	0.20	1.11	0.01	0.00
	15	-0.07	-0.04	0.39	0.35	0.19	0.02	-1.0	-0.5	10.2	2.1	1.4	0.4	-6.06	-0.43	0.21	1.11	0.01	0.00
	20	-0.04	-0.06	0.48	0.36	0.21	0.03	-0.8	-0.8	10.5	2.1	1.6	0.5	-6.13	-0.43	0.21	1.12	0.01	0.00

TABLE A(III)-21 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.11	-0.02	0.80	0.34	0.12	0.01	-1.5	-0.4	9.2	2.5	0.9	0.3	-8.69	-0.18	0.25	1.11	-0.00	0.00
	10	-0.10	-0.04	0.92	0.37	0.13	0.02	-1.4	-0.6	9.8	2.6	1.2	0.5	-8.97	-0.16	0.26	1.11	-0.00	0.00
	15	-0.09	-0.06	1.02	0.37	0.14	0.04	-1.3	-0.8	10.3	2.7	1.4	0.6	-9.26	-0.14	0.28	1.11	-0.00	0.00
	20	-0.07	-0.08	1.09	0.38	0.16	0.05	-1.1	-1.2	10.6	2.7	1.6	0.7	-9.33	-0.14	0.28	1.12	-0.00	0.00
20	5	-0.02	-0.02	0.30	0.26	0.14	0.02	-1.6	-0.4	9.3	3.0	0.9	0.4	-3.59	-0.52	0.12	1.12	0.01	0.00
	10	0.02	-0.05	0.36	0.26	0.16	0.04	-1.7	-0.7	10.1	3.2	1.3	0.6	-3.48	-0.53	0.12	1.12	0.01	0.00
	15	0.07	-0.08	0.42	0.25	0.19	0.06	-1.6	-1.1	10.7	3.4	1.5	0.7	-3.28	-0.55	0.12	1.12	0.01	0.00
	20	0.13	-0.12	0.49	0.24	0.21	0.08	-1.6	-1.5	10.9	3.5	1.9	0.9	-3.23	-0.56	0.12	1.13	0.01	0.00
21	5	-0.02	-0.03	0.28	0.26	0.12	0.02	-1.5	-0.4	7.8	2.9	0.9	0.4	-4.08	-0.40	0.12	1.11	0.01	0.00
	10	0.01	-0.05	0.33	0.25	0.14	0.04	-1.4	-0.7	8.3	3.0	1.2	0.6	-4.05	-0.40	0.12	1.11	0.01	0.00
	15	0.05	-0.08	0.37	0.25	0.16	0.06	-1.2	-1.1	8.5	3.1	1.6	0.8	-3.90	-0.42	0.12	1.11	0.00	0.00
	20	0.10	-0.11	0.42	0.24	0.19	0.08	-0.9	-1.5	8.1	3.1	2.1	1.0	-3.78	-0.43	0.12	1.12	0.00	0.00
22	5	-0.06	-0.01	0.18	0.24	0.21	-0.00	-0.6	-0.2	11.6	1.4	0.9	0.2	-2.26	-0.66	0.05	1.13	0.01	0.00
	10	-0.05	-0.02	0.27	0.25	0.23	0.01	-0.6	-0.3	12.2	1.5	1.1	0.2	-1.99	-0.69	0.05	1.13	0.01	0.00
	15	-0.04	-0.03	0.35	0.25	0.24	0.01	-0.6	-0.5	12.5	1.6	1.2	0.3	-2.04	-0.69	0.05	1.14	0.01	0.00
	20	-0.00	-0.05	0.45	0.24	0.26	0.02	-0.6	-0.7	12.8	1.6	1.3	0.3	-2.12	-0.70	0.06	1.14	0.01	0.00
23	5	-0.02	-0.01	0.34	0.13	0.17	0.00	-0.3	-0.2	8.6	0.9	1.0	0.2	-2.80	-0.48	0.09	1.12	0.01	0.00
	10	-0.01	-0.02	0.40	0.13	0.18	0.01	-0.2	-0.4	8.8	0.9	1.1	0.2	-2.64	-0.51	0.09	1.12	0.01	0.00
	15	0.02	-0.03	0.46	0.12	0.19	0.02	-0.1	-0.5	8.9	0.9	1.2	0.3	-2.71	-0.52	0.09	1.12	0.01	0.00
	20	0.04	-0.04	0.52	0.12	0.20	0.02	-0.1	-0.7	9.0	0.9	1.3	0.3	-2.80	-0.52	0.09	1.13	0.01	0.00
24	5	-0.09	-0.01	0.27	0.27	0.22	-0.00	-0.8	-0.3	11.9	1.6	1.1	0.2	-4.02	-0.57	0.07	1.13	0.01	0.00
	10	-0.06	-0.03	0.35	0.28	0.24	0.01	-0.8	-0.5	12.6	1.7	1.3	0.3	-3.54	-0.63	0.07	1.13	0.01	0.00
	15	-0.02	-0.05	0.44	0.27	0.26	0.02	-0.8	-0.7	13.0	1.8	1.5	0.4	-3.65	-0.64	0.08	1.14	0.01	0.00
	20	0.02	-0.07	0.54	0.27	0.28	0.03	-0.8	-1.0	13.3	1.8	1.6	0.4	-3.81	-0.64	0.08	1.14	0.01	0.00
25	5	-0.06	-0.01	0.19	0.34	0.16	0.00	-1.1	-0.2	9.5	2.1	0.9	0.3	-6.18	-0.52	0.07	1.11	0.01	0.00
	10	-0.06	-0.03	0.23	0.35	0.18	0.01	-1.0	-0.5	10.1	2.2	1.2	0.4	-6.38	-0.50	0.07	1.12	0.01	0.00
	15	-0.05	-0.05	0.29	0.36	0.20	0.02	-0.8	-0.7	10.4	2.3	1.5	0.5	-6.62	-0.50	0.07	1.12	0.01	0.00
	20	-0.03	-0.07	0.37	0.37	0.22	0.04	-0.6	-1.1	10.6	2.3	1.7	0.6	-6.89	-0.48	0.07	1.12	0.01	0.00
26	5	-0.10	-0.02	0.22	0.32	0.11	0.02	-1.7	-0.4	8.2	2.9	0.9	0.4	-10.50	-0.23	0.08	1.10	0.01	0.00
	10	-0.10	-0.04	0.30	0.34	0.13	0.03	-1.6	-0.7	8.6	3.0	1.3	0.6	-10.40	-0.24	0.09	1.11	0.01	0.00
	15	-0.07	-0.07	0.38	0.36	0.14	0.05	-1.3	-1.1	8.5	2.9	1.7	0.8	-10.54	-0.24	0.09	1.11	0.00	0.00
	20	-0.04	-0.10	0.46	0.37	0.17	0.07	-0.9	-1.7	8.1	2.8	2.1	1.0	-10.81	-0.23	0.09	1.12	0.00	0.00
27	5	-0.08	-0.03	0.14	0.38	0.13	0.03	-2.1	-0.5	9.4	4.2	1.2	0.6	-7.30	-0.61	0.08	1.13	0.01	0.00
	10	-0.07	-0.06	0.28	0.45	0.15	0.05	-1.8	-1.2	9.4	4.2	1.8	1.1	-7.10	-0.64	0.08	1.13	0.01	0.00
	15	-0.02	-0.12	0.47	0.52	0.18	0.08	-1.4	-2.2	8.0	4.0	2.9	1.6	-6.65	-0.69	0.07	1.14	0.01	0.00
	20	0.06	-0.19	0.71	0.58	0.23	0.12	-0.4	-3.5	5.6	3.4	4.4	2.2	-6.67	-0.71	0.07	1.14	0.01	0.00

TABLE A(III)-22. CONTINUOUS HAY (A,B,C,D SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.77	-4.08	-1.61	34.75	16	5	3.20	-6.17	-3.15	63.92
	10	1.69	-4.00	-1.35	24.18		10	3.25	-6.41	-3.04	56.36
	15	1.66	-3.93	-1.25	20.01		15	3.29	-6.47	-2.92	52.30
	20	1.61	-3.79	-1.22	17.03		20	3.30	-6.55	-2.95	50.36
2	5	2.69	-5.37	-2.57	47.79	17	5	3.35	-6.43	-3.29	64.07
	10	2.65	-5.36	-2.33	37.79		10	3.44	-6.85	-3.22	56.85
	15	2.59	-5.26	-2.15	32.72		15	3.48	-7.02	-3.13	52.99
	20	2.52	-5.09	-2.08	29.43		20	3.50	-7.04	-3.08	50.44
3	5	3.55	-6.12	-3.51	65.39	18	5	3.67	-6.81	-3.63	67.94
	10	3.65	-6.51	-3.46	58.01		10	3.84	-7.35	-3.64	61.44
	15	3.66	-6.58	-3.50	55.56		15	3.90	-7.55	-3.58	58.03
	20	3.65	-6.58	-3.56	54.64		20	3.94	-7.62	-3.55	55.85
4	5	2.95	-6.17	-2.88	54.83	19	5	3.47	-6.68	-3.41	64.65
	10	3.04	-6.58	-2.71	43.76		10	3.66	-7.12	-3.45	57.98
	15	3.06	-6.70	-2.54	38.08		15	3.74	-7.32	-3.39	54.47
	20	3.04	-6.66	-2.45	34.89		20	3.79	-7.41	-3.35	52.08
5	5	3.25	-6.27	-3.19	59.73	22	5	3.47	-6.66	-3.45	68.14
	10	3.29	-6.49	-3.05	51.37		10	3.56	-7.06	-3.43	62.13
	15	3.33	-6.64	-2.97	47.24		15	3.59	-7.14	-3.46	59.96
	20	3.34	-6.61	-2.98	44.97		20	3.61	-7.28	-3.54	59.32
6	5	1.73	-3.87	-1.58	33.70	23	5	4.48	-6.14	-4.44	76.88
	10	1.68	-3.96	-1.22	19.97		10	4.57	-6.44	-4.45	72.42
	15	1.60	-3.84	-0.95	13.88		15	4.62	-6.58	-4.47	70.31
	20	1.53	-3.63	-0.86	10.82		20	4.64	-6.61	-4.51	69.04
7	5	2.31	-4.95	-2.20	43.10	24	5	3.60	-6.58	-3.55	66.53
	10	2.32	-5.13	-1.98	29.44		10	3.68	-6.98	-3.48	60.03
	15	2.32	-5.28	-1.75	22.99		15	3.70	-7.12	-3.43	56.97
	20	2.30	-5.21	-1.49	18.38		20	3.71	-7.12	-3.45	55.26
8	5	3.22	-6.16	-3.17	61.24	25	5	3.58	-6.95	-3.54	68.24
	10	3.36	-6.61	-3.13	52.65		10	3.77	-7.41	-3.65	61.16
	15	3.45	-6.92	-3.08	48.59		15	3.89	-7.68	-3.68	57.78
	20	3.50	-7.00	-3.07	46.14		20	3.95	-7.74	-3.63	55.08
12	5	3.22	-6.07	-3.17	62.69	26	5	3.45	-5.54	-3.40	62.22
	10	3.43	-6.61	-3.26	54.40		10	3.64	-6.08	-3.52	54.12
	15	3.58	-6.96	-3.24	50.52		15	3.77	-6.50	-3.54	50.69
	20	3.66	-7.20	-3.22	48.09		20	3.86	-6.62	-3.61	49.11

TABLE A(III)-23. CONTINUOUS HAY, SPRING FERTILIZATION (A,B,C,D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.48	-0.09	1.93	0.32	0.20	0.08	-15.7	-1.5	44.2	11.4	4.1	1.0	-1.12	-0.00	0.67	1.16	0.00	0.00
	10	-0.56	-0.21	0.97	0.45	0.62	0.15	-20.6	-2.9	56.6	14.7	7.7	1.9	-0.96	-0.02	0.42	1.17	0.02	0.00
	15	-0.76	-0.33	1.49	0.60	0.98	0.22	-25.1	-3.7	67.6	17.3	9.8	2.5	-0.86	-0.02	0.36	1.17	0.03	0.00
	20	-0.99	-0.45	2.11	0.73	1.29	0.30	-28.2	-4.8	75.0	19.2	12.9	3.3	-0.83	-0.02	0.37	1.17	0.02	0.00
2	5	-0.11	-0.08	0.27	0.12	0.21	0.05	-9.0	-1.3	26.1	5.7	3.8	0.8	-0.21	-0.09	0.12	1.17	0.04	-0.00
	10	-0.23	-0.14	-0.01	0.22	0.45	0.08	-10.5	-2.1	30.3	6.6	5.9	1.3	-0.09	-0.10	0.02	1.17	0.05	-0.00
	15	-0.43	-0.20	0.36	0.35	0.64	0.11	-11.8	-2.6	33.9	7.3	7.1	1.6	0.03	-0.11	-0.03	1.18	0.06	-0.00
	20	-0.73	-0.24	1.06	0.52	0.78	0.13	-11.9	-3.3	34.0	7.3	9.1	2.0	0.02	-0.11	-0.04	1.18	0.05	0.00
3	5	0.02	0.01	0.20	0.05	0.17	0.03	0.7	0.1	16.2	2.5	2.2	0.3	-0.00	0.00	0.24	1.16	0.03	0.00
	10	0.02	0.01	-0.02	0.04	0.30	0.04	0.7	0.1	17.1	2.6	3.1	0.5	-0.00	0.00	0.17	1.16	0.04	0.00
	15	0.02	0.01	-0.10	0.04	0.40	0.06	0.7	0.2	17.2	2.6	3.5	0.5	-0.00	0.00	0.16	1.16	0.04	0.00
	20	0.02	0.01	-0.12	0.04	0.49	0.07	0.7	0.2	17.0	2.6	3.7	0.6	-0.00	0.00	0.14	1.16	0.04	0.00
4	5	-0.45	-0.03	1.23	0.25	0.06	0.03	-6.7	-1.0	15.7	4.4	1.7	0.6	-2.21	0.01	0.82	1.15	-0.01	0.00
	10	-0.50	-0.08	1.39	0.31	0.15	0.05	-7.9	-1.6	16.1	5.0	3.2	1.0	-2.08	-0.00	0.76	1.15	-0.00	0.00
	15	-0.49	-0.14	1.36	0.33	0.25	0.08	-8.6	-2.1	17.4	5.4	4.1	1.3	-1.96	-0.01	0.71	1.16	0.00	0.00
	20	-0.53	-0.19	1.50	0.35	0.35	0.11	-8.9	-2.5	18.1	5.6	4.9	1.5	-1.82	-0.02	0.69	1.16	0.00	0.00
5	5	-0.08	-0.05	0.25	0.06	0.10	0.03	-4.8	-0.7	11.0	2.7	1.2	0.4	-1.51	-0.14	0.34	1.15	0.03	0.00
	10	-0.04	-0.09	0.15	0.06	0.18	0.04	-5.4	-1.1	11.1	3.0	1.7	0.5	-1.39	-0.15	0.28	1.16	0.04	0.00
	15	0.00	-0.13	0.10	0.06	0.25	0.06	-5.8	-1.3	11.3	3.1	1.9	0.6	-1.27	-0.16	0.25	1.16	0.04	0.00
	20	-0.02	-0.16	0.20	0.07	0.30	0.08	-6.0	-1.4	11.2	3.2	2.2	0.7	-1.31	-0.16	0.27	1.16	0.04	0.00
6	5	-0.73	-0.07	2.00	0.44	0.14	0.06	-18.6	-2.0	41.0	12.5	3.4	1.2	-2.54	0.05	1.13	1.16	-0.02	0.00
	10	-0.78	-0.21	3.65	0.45	0.22	0.15	-29.0	-4.5	55.6	18.7	8.5	2.9	-2.18	0.02	1.04	1.16	-0.01	0.00
	15	-0.72	-0.40	3.47	0.48	0.56	0.26	-40.8	-5.2	76.3	26.0	10.6	3.4	-2.02	0.01	0.94	1.17	-0.00	0.00
	20	-0.57	-0.63	3.93	0.28	0.93	0.40	-50.9	-4.9	94.9	31.8	10.6	3.5	-1.56	-0.03	0.99	1.17	-0.01	0.00
7	5	-0.62	-0.05	1.20	0.44	0.11	0.04	-10.5	-1.4	23.7	8.0	2.4	1.0	-2.29	0.01	1.05	1.15	-0.01	0.00
	10	-0.90	-0.11	2.02	0.63	0.17	0.09	-12.9	-3.8	24.2	9.4	6.9	2.6	-2.29	0.01	1.02	1.16	-0.01	0.00
	15	-1.34	-0.18	2.61	0.96	0.31	0.13	-14.8	-5.6	26.9	10.6	10.4	3.9	-2.41	0.02	0.98	1.16	-0.00	0.00
	20	-1.53	-0.29	3.12	1.06	0.51	0.20	-19.5	-6.4	34.9	13.4	12.1	4.5	-2.29	0.01	0.99	1.16	-0.01	0.00
8	5	-0.21	-0.03	0.44	0.16	0.09	0.02	-4.2	-0.6	10.3	2.9	1.0	0.4	-3.64	0.06	0.84	1.12	-0.01	0.00
	10	-0.26	-0.06	0.46	0.20	0.14	0.04	-4.7	-1.0	10.6	3.2	1.4	0.6	-3.73	0.07	0.83	1.13	-0.01	0.00
	15	-0.27	-0.09	0.49	0.23	0.20	0.05	-4.9	-1.2	10.7	3.3	1.6	0.7	-3.69	0.06	0.80	1.13	-0.00	0.00
	20	-0.31	-0.12	0.60	0.26	0.24	0.07	-5.1	-1.4	10.8	3.4	1.8	0.8	-3.65	0.06	0.80	1.14	-0.00	0.00
12	5	-0.25	-0.03	0.58	0.20	0.06	0.03	-4.4	-0.6	9.7	3.4	0.9	0.4	-3.07	0.04	0.92	1.11	-0.01	0.00
	10	-0.29	-0.05	0.71	0.24	0.10	0.04	-4.6	-1.0	10.0	3.5	1.2	0.7	-3.25	0.06	0.93	1.12	-0.01	0.00
	15	-0.32	-0.08	0.71	0.26	0.15	0.06	-4.8	-1.3	9.8	3.6	1.3	0.8	-3.34	0.07	0.93	1.12	-0.01	0.00
	20	-0.32	-0.12	0.82	0.26	0.19	0.08	-5.0	-1.4	9.6	3.7	1.5	0.9	-3.26	0.06	0.91	1.12	-0.01	0.00

TABLE A(III)-23 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
16	5	0.03	0.01	0.90	0.16	0.09	0.03	0.8	0.1	16.3	3.8	1.8	0.4	0.00	-0.00	0.53	1.14	0.01	0.00
	10	0.03	0.01	0.86	0.15	0.19	0.05	0.9	0.1	17.8	4.1	2.3	0.5	0.00	-0.00	0.49	1.15	0.01	0.00
	15	0.04	0.01	1.01	0.18	0.29	0.07	1.0	0.1	19.1	4.4	2.4	0.6	0.00	-0.00	0.50	1.15	0.01	0.00
	20	0.04	0.01	0.99	0.22	0.38	0.08	1.0	0.2	19.4	4.4	2.6	0.6	-0.00	0.00	0.49	1.15	0.01	0.00
17	5	-0.11	-0.03	0.21	0.10	0.09	0.02	-3.8	-0.5	9.4	2.5	0.9	0.3	-2.82	-0.02	0.58	1.13	0.01	0.00
	10	-0.10	-0.06	0.20	0.12	0.15	0.04	-4.2	-0.7	9.7	2.7	1.1	0.4	-2.63	-0.04	0.51	1.14	0.02	0.00
	15	-0.11	-0.09	0.21	0.14	0.20	0.05	-4.6	-0.8	9.9	2.9	1.2	0.5	-2.63	-0.04	0.49	1.14	0.02	0.00
	20	-0.16	-0.11	0.29	0.17	0.24	0.06	-4.9	-0.9	10.0	3.0	1.2	0.5	-2.64	-0.04	0.50	1.14	0.02	0.00
18	5	-0.14	-0.03	0.29	0.16	0.06	0.02	-3.2	-0.5	7.1	2.5	0.8	0.3	-3.46	0.05	0.70	1.11	-0.00	0.00
	10	-0.16	-0.05	0.29	0.18	0.10	0.03	-3.4	-0.7	7.1	2.6	0.9	0.5	-3.37	0.04	0.66	1.11	-0.00	0.00
	15	-0.17	-0.07	0.30	0.20	0.14	0.05	-3.6	-0.8	7.2	2.7	0.9	0.5	-3.43	0.05	0.66	1.12	-0.00	0.00
	20	-0.19	-0.09	0.35	0.22	0.17	0.06	-3.8	-0.8	7.2	2.8	1.0	0.5	-3.44	0.05	0.65	1.12	0.00	0.00
19	5	-0.20	-0.03	0.28	0.22	0.07	0.03	-4.0	-0.6	7.9	3.4	0.8	0.4	-3.11	0.06	0.74	1.10	-0.01	0.00
	10	-0.21	-0.06	0.25	0.26	0.11	0.04	-4.2	-0.9	7.6	3.5	1.0	0.6	-3.20	0.07	0.71	1.11	-0.01	0.00
	15	-0.24	-0.09	0.25	0.28	0.16	0.06	-4.6	-1.0	7.1	3.7	1.2	0.7	-3.15	0.07	0.69	1.12	-0.01	0.00
	20	-0.27	-0.11	0.28	0.31	0.19	0.07	-4.8	-1.0	6.9	3.8	1.3	0.7	-3.28	0.08	0.70	1.12	-0.01	0.00
22	5	-0.10	-0.02	0.11	0.08	0.09	0.02	-3.0	-0.4	8.9	1.7	0.9	0.2	-2.64	-0.03	0.58	1.13	0.01	0.00
	10	-0.10	-0.05	0.11	0.08	0.14	0.02	-3.3	-0.6	9.0	1.9	1.0	0.3	-2.48	-0.04	0.52	1.13	0.02	0.00
	15	-0.12	-0.07	0.14	0.09	0.18	0.03	-3.5	-0.6	9.0	1.9	1.0	0.3	-2.46	-0.05	0.52	1.14	0.02	0.00
	20	-0.11	-0.08	0.12	0.09	0.22	0.04	-3.5	-0.7	8.9	1.9	1.0	0.3	-2.40	-0.05	0.49	1.14	0.02	0.00
23	5	0.02	-0.03	-0.03	0.01	0.06	0.02	-2.1	-0.4	5.4	1.2	0.8	0.2	-1.22	-0.11	0.21	1.13	0.02	0.00
	10	0.05	-0.05	-0.09	0.01	0.10	0.02	-2.3	-0.5	5.1	1.3	0.9	0.3	-1.16	-0.12	0.19	1.13	0.03	0.00
	15	0.06	-0.06	-0.12	0.01	0.14	0.03	-2.4	-0.5	5.0	1.3	0.9	0.3	-1.14	-0.12	0.18	1.14	0.03	0.00
	20	0.06	-0.08	-0.11	0.01	0.16	0.04	-2.4	-0.6	5.0	1.3	0.9	0.3	-1.15	-0.12	0.19	1.14	0.03	0.00
24	5	-0.10	-0.03	0.15	0.08	0.08	0.02	-3.5	-0.5	7.9	2.1	0.9	0.3	-2.81	-0.02	0.53	1.13	0.01	0.00
	10	-0.07	-0.06	0.08	0.08	0.14	0.03	-3.9	-0.7	7.9	2.3	1.1	0.4	-2.63	-0.03	0.47	1.14	0.01	0.00
	15	-0.07	-0.09	0.05	0.09	0.19	0.05	-4.1	-0.7	7.9	2.4	1.1	0.4	-2.59	-0.04	0.45	1.14	0.02	0.00
	20	-0.10	-0.11	0.12	0.10	0.22	0.05	-4.2	-0.8	7.8	2.4	1.2	0.4	-2.58	-0.04	0.45	1.14	0.02	0.00
25	5	-0.21	-0.03	0.33	0.19	0.07	0.02	-3.7	-0.5	8.1	2.8	0.9	0.4	-3.14	0.05	0.80	1.10	-0.01	0.00
	10	-0.25	-0.05	0.33	0.22	0.11	0.04	-3.9	-0.8	8.2	2.9	1.0	0.5	-3.33	0.07	0.81	1.11	-0.01	0.00
	15	-0.29	-0.03	0.39	0.24	0.15	0.05	-3.9	-1.0	8.2	3.0	1.1	0.7	-3.46	0.08	0.84	1.11	-0.01	0.00
	20	-0.33	-0.10	0.49	0.27	0.19	0.06	-4.2	-1.1	8.1	3.1	1.1	0.7	-3.47	0.08	0.84	1.11	-0.01	0.00
26	5	-0.24	-0.03	0.22	0.20	0.06	0.03	-3.7	-0.6	7.6	3.6	1.0	0.5	-4.05	0.08	1.10	1.08	-0.02	0.01
	10	-0.31	-0.05	0.35	0.24	0.09	0.04	-3.6	-1.2	7.6	3.5	1.4	0.9	-4.14	0.09	1.10	1.09	-0.02	0.01
	15	-0.33	-0.08	0.41	0.26	0.14	0.07	-3.4	-1.6	7.5	3.3	1.6	1.2	-4.24	0.10	1.10	1.10	-0.02	0.01
	20	-0.34	-0.11	0.49	0.27	0.19	0.09	-3.3	-1.9	6.9	3.1	1.8	1.4	-4.27	0.11	1.10	1.10	-0.02	0.01

TABLE A(III)-24. CONTINUOUS HAY, FALL FERTILIZATION (A,B,C,D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.27	-0.06	1.15	0.30	0.54	0.07	-9.9	-1.3	48.3	10.5	3.4	1.0	-1.12	-0.00	0.00	1.16	0.01	0.00
	10	-0.29	-0.15	3.17	0.41	0.57	0.14	-14.6	-2.7	59.8	13.9	6.1	1.9	-0.96	-0.02	0.01	1.17	0.01	0.00
	15	-0.40	-0.26	4.03	0.54	0.71	0.22	-19.5	-3.6	65.5	16.8	8.9	2.5	-0.86	-0.02	0.01	1.17	0.01	0.00
	20	-0.55	-0.36	4.26	0.66	0.93	0.29	-23.3	-4.7	69.6	18.8	12.7	3.3	-0.83	-0.02	0.01	1.17	0.01	0.00
2	5	-0.04	-0.05	3.92	0.11	0.12	0.05	-5.1	-1.1	29.8	5.2	3.0	0.8	-0.21	-0.09	0.01	1.17	0.01	-0.00
	10	-0.08	-0.10	4.98	0.19	0.13	0.08	-6.2	-2.0	33.6	6.0	4.7	1.3	-0.09	-0.10	0.01	1.17	0.01	-0.00
	15	-0.17	-0.15	5.75	0.30	0.19	0.11	-7.9	-2.5	34.0	6.8	6.3	1.6	0.03	-0.11	0.01	1.18	0.01	-0.00
	20	-0.34	-0.19	6.28	0.46	0.25	0.13	-8.6	-3.2	31.9	7.0	8.6	2.0	0.02	-0.11	0.01	1.18	0.01	0.00
3	5	0.02	0.01	1.02	0.05	0.21	0.03	0.7	0.1	15.6	2.5	1.9	0.3	0.00	-0.00	0.00	1.16	0.01	0.00
	10	0.02	0.01	1.30	0.04	0.23	0.04	0.7	0.1	16.3	2.6	2.8	0.5	0.00	-0.00	0.00	1.16	0.00	0.00
	15	0.02	0.01	1.47	0.04	0.27	0.06	0.7	0.2	16.2	2.6	3.3	0.5	0.00	-0.00	0.00	1.16	0.00	0.00
	20	0.02	0.01	1.62	0.04	0.30	0.07	0.7	0.2	15.8	2.6	3.6	0.6	0.00	-0.00	0.01	1.16	0.00	0.00
4	5	-0.18	-0.02	0.81	0.21	0.28	0.03	-3.0	-0.6	21.1	3.8	2.1	0.5	-2.21	0.01	0.04	1.15	0.00	0.00
	10	-0.20	-0.05	1.43	0.26	0.30	0.05	-3.4	-1.2	23.5	4.3	3.6	0.9	-2.08	-0.00	0.05	1.15	0.00	0.00
	15	-0.19	-0.08	1.93	0.29	0.32	0.07	-3.9	-1.8	25.0	4.6	4.4	1.2	-1.96	-0.01	0.06	1.16	0.00	0.00
	20	-0.18	-0.12	2.22	0.30	0.37	0.10	-4.0	-2.3	25.7	4.8	5.0	1.5	-1.82	-0.02	0.06	1.16	0.00	0.00
5	5	-0.00	-0.02	1.27	0.05	0.19	0.02	-1.4	-0.4	17.2	2.1	1.7	0.3	-1.51	-0.14	0.06	1.15	0.00	0.00
	10	0.01	-0.04	1.71	0.05	0.19	0.04	-1.6	-0.6	18.5	2.3	2.4	0.5	-1.39	-0.15	0.07	1.16	0.00	0.00
	15	0.03	-0.05	2.07	0.05	0.20	0.05	-1.7	-0.8	19.0	2.4	2.8	0.6	-1.27	-0.16	0.07	1.16	0.00	0.00
	20	0.04	-0.07	2.24	0.06	0.23	0.06	-1.8	-1.1	18.9	2.4	3.1	0.7	-1.31	-0.16	0.07	1.16	0.00	0.00
6	5	-0.44	-0.06	-0.62	0.39	0.57	0.06	-12.4	-1.6	47.1	11.6	3.6	1.2	-2.54	0.05	0.03	1.16	0.01	0.00
	10	-0.49	-0.15	0.16	0.42	0.75	0.14	-21.2	-4.2	64.9	17.4	7.7	2.9	-2.18	0.02	0.07	1.16	0.00	0.00
	15	-0.43	-0.30	1.17	0.43	0.93	0.24	-33.0	-5.3	82.8	24.8	8.4	3.5	-2.02	0.01	0.11	1.17	-0.00	0.00
	20	-0.25	-0.50	0.82	0.24	1.28	0.38	-44.9	-4.9	92.2	31.0	9.6	3.5	-1.56	-0.03	0.10	1.17	-0.00	0.00
7	5	-0.40	-0.04	0.74	0.40	0.29	0.04	-6.9	-1.2	27.1	7.4	2.6	0.9	-2.29	0.01	0.10	1.15	0.00	0.00
	10	-0.58	-0.09	2.07	0.58	0.33	0.08	-8.1	-3.5	32.1	8.6	5.9	2.6	-2.29	0.01	0.17	1.16	-0.00	0.00
	15	-0.89	-0.14	3.95	0.90	0.30	0.12	-9.6	-5.5	35.3	9.7	8.6	3.9	-2.41	0.02	0.26	1.16	-0.01	0.00
	20	-1.01	-0.24	4.13	0.98	0.43	0.19	-14.4	-6.5	39.1	12.7	10.7	4.6	-2.29	0.01	0.24	1.16	-0.01	0.00
8	5	-0.11	-0.02	0.75	0.14	0.16	0.02	-1.8	-0.3	14.3	2.5	1.5	0.3	-3.64	0.06	0.23	1.12	-0.01	0.00
	10	-0.13	-0.03	1.16	0.18	0.17	0.03	-1.9	-0.6	15.4	2.7	2.2	0.5	-3.73	0.07	0.27	1.13	-0.01	0.00
	15	-0.13	-0.05	1.48	0.20	0.18	0.05	-2.0	-0.8	15.9	2.8	2.6	0.6	-3.69	0.06	0.30	1.13	-0.01	0.00
	20	-0.15	-0.06	1.70	0.23	0.20	0.06	-2.0	-1.0	16.1	2.8	2.9	0.7	-3.65	0.06	0.31	1.14	-0.01	0.00
12	5	-0.16	-0.02	0.64	0.18	0.12	0.02	-2.6	-0.4	12.2	3.1	1.2	0.4	-3.07	0.04	0.23	1.11	-0.00	0.00
	10	-0.19	-0.04	0.93	0.22	0.14	0.04	-2.6	-0.7	12.8	3.2	1.9	0.6	-3.25	0.06	0.29	1.12	-0.01	0.00
	15	-0.21	-0.05	1.14	0.24	0.15	0.05	-2.6	-0.9	13.2	3.3	2.3	0.8	-3.34	0.07	0.33	1.12	-0.01	0.00
	20	-0.19	-0.07	1.17	0.24	0.18	0.07	-2.6	-1.1	13.4	3.3	2.5	0.9	-3.26	0.06	0.35	1.12	-0.01	0.00

TABLE A(III)-24 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
16	5	0.03	0.01	1.69	0.16	0.13	0.03	0.8	0.1	15.5	3.8	1.6	0.4	-0.00	0.00	0.18	1.14	-0.00	0.00
	10	0.03	0.01	2.05	0.15	0.13	0.05	0.9	0.1	16.9	4.1	2.1	0.5	-0.00	0.00	0.20	1.15	-0.00	0.00
	15	0.04	0.10	2.17	0.18	0.15	0.07	1.0	0.1	18.0	4.4	2.7	0.6	0.00	-0.00	0.20	1.15	-0.00	0.00
	20	0.04	0.01	2.39	0.22	0.22	0.08	1.0	0.2	18.2	4.4	2.7	0.6	-0.00	0.00	0.20	1.15	-0.00	0.00
17	5	-0.05	-0.01	0.83	0.09	0.16	0.02	-1.3	-0.3	13.8	2.1	1.4	0.3	-2.82	-0.02	0.28	1.13	-0.00	0.00
	10	-0.05	-0.03	1.16	0.11	0.17	0.03	-1.4	-0.4	14.9	2.2	1.9	0.3	-2.63	-0.04	0.32	1.14	-0.01	0.00
	15	-0.05	-0.04	1.49	0.13	0.17	0.04	-1.5	-0.5	15.7	2.3	2.0	0.4	-2.63	-0.04	0.35	1.14	-0.01	0.00
	20	-0.06	-0.05	1.70	0.15	0.19	0.05	-1.6	-0.6	16.2	2.4	2.1	0.4	-2.64	-0.04	0.35	1.14	-0.01	0.00
18	5	-0.08	-0.02	0.95	0.15	0.09	0.02	-1.4	-0.3	10.2	2.2	1.2	0.3	-3.46	0.05	0.41	1.11	-0.01	0.00
	10	-0.08	-0.03	1.22	0.17	0.10	0.03	-1.5	-0.4	10.6	2.3	1.5	0.4	-3.37	0.04	0.45	1.11	-0.01	0.00
	15	-0.09	-0.04	1.46	0.19	0.10	0.04	-1.5	-0.5	11.0	2.4	1.7	0.5	-3.43	0.05	0.48	1.12	-0.02	0.00
	20	-0.09	-0.05	1.68	0.21	0.10	0.05	-1.5	-0.6	11.3	2.4	1.7	0.5	-3.44	0.05	0.51	1.12	-0.02	0.00
19	5	-0.12	-0.02	0.94	0.21	0.08	0.02	-2.3	-0.4	10.4	3.1	1.1	0.4	-3.11	0.06	0.45	1.10	-0.01	0.00
		-0.14	-0.04	1.25	0.24	0.09	0.04	-2.3	-0.6	10.9	3.2	1.5	0.6	-3.20	0.07	0.52	1.11	-0.02	0.00
		-0.15	-0.06	1.42	0.26	0.11	0.05	-2.3	-0.7	11.3	3.3	1.7	0.7	-3.15	0.07	0.53	1.12	-0.02	0.00
		-0.16	-0.08	1.68	0.29	0.11	0.07	-2.4	-0.8	11.6	3.4	1.8	0.7	-3.28	0.08	0.58	1.12	-0.03	0.00
22	5	-0.05	-0.01	0.69	0.07	0.15	0.01	-1.1	-0.2	12.5	1.4	1.2	0.2	-2.64	-0.03	0.21	1.13	0.00	0.00
	10	-0.05	-0.02	0.88	0.07	0.16	0.02	-1.1	-0.3	13.1	1.5	1.5	0.2	-2.48	-0.04	0.23	1.13	0.00	0.00
	15	-0.06	-0.03	1.01	0.08	0.17	0.03	-1.1	-0.3	13.2	1.5	1.7	0.3	-2.46	-0.05	0.23	1.14	0.00	0.00
	20	-0.06	-0.04	1.22	0.08	0.17	0.03	-1.1	-0.4	13.1	1.5	1.7	0.3	-2.40	-0.05	0.24	1.14	-0.00	0.00
23	5	0.03	-0.01	0.68	0.01	0.14	0.01	-0.4	-0.2	8.9	0.9	1.0	0.2	-1.22	-0.11	0.13	1.13	0.00	0.00
	10	0.03	-0.02	0.79	0.01	0.15	0.02	-0.3	-0.3	9.1	0.9	1.3	0.2	-1.16	-0.12	0.14	1.13	0.00	0.00
	15	0.05	-0.03	0.85	0.01	0.15	0.02	-0.3	-0.3	9.1	0.9	1.4	0.2	-1.14	-0.12	0.15	1.14	0.00	0.00
	20	0.05	-0.04	0.91	0.01	0.16	0.03	-0.3	-0.3	9.1	0.9	1.4	0.2	-1.15	-0.12	0.15	1.14	0.00	0.00
24	5	-0.03	-0.01	1.25	0.07	0.14	0.02	-1.0	-0.3	12.7	1.7	1.2	0.2	-2.81	-0.02	0.18	1.13	-0.00	0.00
	10	-0.02	-0.02	1.56	0.07	0.14	0.03	-1.0	-0.4	13.5	1.8	1.6	0.3	-2.63	-0.03	0.20	1.14	-0.00	0.00
	15	-0.01	-0.03	1.74	0.08	0.14	0.04	-1.1	-0.5	13.9	1.8	1.7	0.4	-2.59	-0.04	0.21	1.14	-0.00	0.00
	20	-0.02	-0.04	1.86	0.09	0.15	0.04	-1.1	-0.5	13.9	1.9	1.8	0.4	-2.58	-0.04	0.21	1.14	-0.00	0.00
25	5	-0.21	-0.03	0.76	0.18	0.10	0.02	-3.0	-0.4	10.6	2.7	1.1	0.3	-3.14	0.05	0.29	1.10	-0.00	0.00
	10	-0.25	-0.04	1.04	0.21	0.11	0.03	-3.0	-0.7	10.8	2.7	1.6	0.5	-3.33	0.07	0.36	1.11	-0.01	0.00
	15	-0.29	-0.05	1.19	0.24	0.13	0.05	-3.0	-0.8	10.8	2.7	1.7	0.6	-3.46	0.08	0.39	1.11	-0.01	0.00
	20	-0.31	-0.07	1.28	0.26	0.14	0.06	-3.1	-0.9	11.1	2.8	1.8	0.7	-3.47	0.08	0.40	1.11	-0.01	0.00
26	5	-0.17	-0.02	0.21	0.19	0.10	0.03	-2.4	-0.5	9.3	3.4	1.2	0.5	-4.05	0.08	0.12	1.08	0.01	0.01
	10	-0.20	-0.03	0.40	0.22	0.12	0.04	-2.2	-1.0	9.2	3.3	1.9	0.9	-4.14	0.09	0.18	1.09	0.00	0.01
	15	-0.20	-0.06	0.58	0.24	0.14	0.06	-2.0	-1.3	9.0	3.1	2.2	1.1	-4.24	0.10	0.22	1.10	-0.00	0.01
	20	-0.20	-0.08	0.67	0.25	0.16	0.08	-1.6	-1.6	8.6	2.8	2.5	1.4	-4.27	0.11	0.24	1.10	-0.00	0.01

TABLE A(III)-25. SOYBEANS, NO TILLAGE (A,B,C,D SOILS)

Region	AW	A	B	A'	B'	Region	AW	A	B	A'	B'	Region	AW	A	B	A'	B'
1	5	2.23	-5.16	-2.17	33.94	9	5	2.36	-4.86	-2.27	52.44	17	5	3.72	-7.26	-3.71	74.36
	10	2.13	-4.99	-2.02	47.04		10	2.20	-4.61	-1.99	37.07		10	3.74	-7.46	-3.68	67.41
	15	2.03	-4.79	-1.87	32.04		15	2.10	-4.48	-1.81	26.98		15	3.70	-7.42	-3.63	62.35
	20	1.92	-4.52	-1.76	25.19		20	1.99	-4.31	-1.57	19.42		20	3.67	-7.40	-3.59	57.94
2	5	3.01	-6.09	-2.83	60.09	10	5	2.94	-5.64	-2.89	63.31	18	5	4.25	-7.91	-4.24	79.99
	10	2.93	-5.96	-2.83	49.74		10	2.85	-5.48	-2.68	49.85		10	4.24	-8.03	-4.20	73.49
	15	2.84	-5.82	-2.70	42.08		15	2.73	-5.29	-2.54	39.90		15	4.18	-7.97	-4.13	68.62
	20	2.74	-5.56	-2.59	36.28		20	2.63	-5.13	-2.41	31.77		20	4.14	-7.97	-4.09	64.52
3	5	3.88	-6.81	-3.87	74.88	11	5	3.51	-6.79	-3.47	71.71	19	5	4.06	-7.49	-4.03	76.32
	10	3.91	-7.02	-3.87	64.33		10	3.43	-6.69	-3.32	60.40		10	4.07	-7.65	-3.99	69.41
	15	3.89	-7.01	-3.89	66.04		15	3.38	-6.69	-3.21	52.05		15	4.02	-7.61	-3.91	64.24
	20	3.87	-7.04	-3.86	63.28		20	3.30	-6.62	-3.09	44.97		20	3.97	-7.62	-3.86	59.96
4	5	3.36	-6.99	-3.33	66.36	12	5	3.88	-7.21	-3.86	75.74	20	5	4.21	-7.47	-4.20	78.42
	10	3.38	-7.19	-3.28	56.86		10	3.91	-7.39	-3.85	67.97		10	4.20	-7.56	-4.15	70.96
	15	3.32	-7.15	-3.16	50.04		15	3.93	-7.49	-3.82	62.32		15	4.17	-7.60	-4.10	65.22
	20	3.26	-7.11	-3.13	44.82		20	3.89	-7.56	-3.76	57.48		20	4.12	-7.62	-4.02	60.24
5	5	3.56	-6.93	-3.54	69.50	13	5	4.49	-6.97	-4.47	80.28	21	5	4.49	-7.27	-4.47	90.01
	10	3.58	-7.05	-3.51	61.74		10	4.46	-7.95	-4.37	72.43		10	4.49	-7.40	-4.45	72.83
	15	3.55	-7.06	-3.44	56.40		15	4.44	-7.06	-4.30	66.64		15	4.47	-7.46	-4.41	67.41
	20	3.52	-7.02	-3.44	51.93		20	4.41	-7.13	-4.19	61.46		20	4.41	-7.45	-4.36	62.74
6	5	2.10	-4.70	-2.00	48.79	14	5	4.47	-7.06	-4.45	79.44	25	5	4.08	-7.92	-4.06	78.11
	10	2.01	-4.69	-1.75	34.62		10	4.45	-7.13	-4.38	72.04		10	4.13	-8.04	-4.07	70.54
	15	1.90	-4.49	-1.54	25.75		15	4.40	-7.14	-4.30	66.25		15	4.13	-8.07	-4.06	65.37
	20	1.79	-4.25	-1.41	19.11		20	4.35	-7.24	-4.23	61.43		20	4.11	-8.04	-4.00	61.12
7	5	2.68	-5.70	-2.61	57.56	15	5	4.57	-6.65	-4.56	78.53	26	5	4.03	-6.66	-4.02	74.75
	10	2.70	-5.91	-2.47	44.34		10	4.58	-6.90	-4.56	71.79		10	4.08	-6.90	-4.05	67.48
	15	2.63	-5.91	-2.24	35.40		15	4.57	-7.04	-4.55	67.00		15	4.10	-7.07	-4.09	63.14
	20	2.56	-5.78	-2.05	28.30		20	4.55	-7.04	-4.53	63.03		20	4.10	-7.07	-4.08	59.55
8	5	3.65	-6.96	-3.61	71.26	16	5	3.55	-6.72	-3.53	72.58	27	5	3.97	-6.68	-3.96	71.65
	10	3.70	-7.21	-3.61	63.29		10	3.52	-6.85	-3.45	65.22		10	4.01	-6.94	-4.00	63.99
	15	3.70	-7.28	-3.56	57.78		15	3.48	-6.79	-3.37	59.71		15	4.03	-7.21	-4.03	58.88
	20	3.67	-7.35	-3.53	53.54		20	3.45	-6.81	-3.36	55.67		20	4.03	-7.30	-4.01	54.75

TABLE A(III)-26 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.20	-0.04	2.17	0.28	0.15	0.05	-5.7	-0.5	25.5	6.4	1.3	0.5	-1.33	-0.02	0.71	1.16	-0.01	0.00
	10	-0.22	-0.10	2.14	0.32	0.31	0.10	-7.5	-0.8	28.0	7.8	1.9	0.7	-1.32	-0.02	0.58	1.17	0.01	0.00
	15	-0.41	-0.16	1.99	0.46	0.52	0.15	-9.4	-1.5	30.4	9.2	3.2	1.2	-1.48	-0.00	0.47	1.17	0.02	0.00
	20	-0.65	-0.24	2.67	0.67	0.70	0.21	-11.0	-2.9	32.6	10.3	6.4	2.4	-1.52	0.00	0.49	1.17	0.01	0.00
2	5	-0.05	-0.04	0.35	0.09	0.22	0.04	-3.6	-0.5	19.3	3.8	1.7	0.4	-0.35	-0.15	0.16	1.17	0.04	-0.00
	10	-0.09	-0.07	0.38	0.14	0.33	0.06	-4.4	-0.8	20.5	4.3	2.2	0.7	-0.24	-0.16	0.09	1.17	0.05	-0.00
	15	-0.20	-0.11	0.43	0.22	0.45	0.09	-5.1	-1.3	20.4	4.7	3.3	1.0	-0.03	-0.18	0.02	1.17	0.05	-0.00
	20	-0.37	-0.14	0.86	0.35	0.55	0.11	-5.4	-1.9	19.4	4.7	4.8	1.5	-0.07	-0.17	0.03	1.17	0.05	0.00
3	5	-0.03	-0.02	0.28	0.04	0.14	0.02	-1.3	-0.2	10.6	1.4	1.0	0.2	-0.95	-0.13	0.28	1.15	0.03	0.00
	10	-0.01	-0.03	0.16	0.03	0.19	0.03	-1.5	-0.3	10.5	1.5	1.1	0.2	-0.84	-0.15	0.22	1.16	0.04	0.00
	15	0.00	-0.04	0.13	0.02	0.24	0.03	-1.6	-0.3	10.3	1.5	1.2	0.3	-0.83	-0.15	0.21	1.16	0.04	0.00
	20	0.02	-0.06	0.01	0.02	0.29	0.04	-1.7	-0.4	10.1	1.6	1.2	0.3	-0.77	-0.16	0.17	1.16	0.04	0.00
4	5	-0.18	-0.02	1.51	0.20	0.07	0.02	-2.7	-0.4	13.9	3.1	1.1	0.4	-2.54	-0.03	0.86	1.14	-0.01	0.00
	10	-0.17	-0.04	1.62	0.22	0.13	0.04	-3.1	-0.6	14.4	3.4	1.6	0.5	-2.35	-0.05	0.79	1.15	-0.01	0.00
	15	-0.16	-0.07	1.58	0.23	0.21	0.07	-3.4	-0.8	14.6	3.7	2.1	0.7	-2.39	-0.05	0.75	1.15	-0.00	0.00
	20	-0.18	-0.11	1.59	0.25	0.30	0.09	-3.5	-1.2	14.0	3.7	2.9	1.0	-2.39	-0.05	0.71	1.16	0.00	0.00
5	5	-0.03	-0.02	0.43	0.06	0.12	0.03	-1.9	-0.3	11.2	2.3	1.0	0.3	-2.08	-0.18	0.38	1.15	0.03	0.00
	10	-0.00	-0.04	0.39	0.06	0.18	0.04	-2.2	-0.4	11.3	2.5	1.2	0.4	-1.95	-0.20	0.34	1.16	0.03	0.00
	15	0.02	-0.06	0.30	0.06	0.24	0.06	-2.4	-0.6	11.1	2.6	1.6	0.5	-1.87	-0.21	0.30	1.16	0.04	0.00
	20	0.02	-0.08	0.25	0.06	0.31	0.07	-2.5	-0.8	10.7	2.6	1.9	0.6	-1.97	-0.21	0.29	1.16	0.04	0.00
6	5	-0.42	-0.03	3.01	0.39	0.03	0.05	-7.5	-0.6	25.5	8.3	1.4	0.6	-3.68	0.07	1.07	1.15	-0.03	0.00
	10	-0.28	-0.11	3.54	0.34	0.12	0.11	-10.5	-1.3	30.1	10.8	2.6	1.2	-2.64	-0.03	0.95	1.16	-0.02	0.00
	15	-0.23	-0.21	2.80	0.31	0.41	0.19	-13.3	-2.4	34.8	13.2	4.7	2.1	-2.55	-0.03	0.85	1.16	-0.01	0.00
	20	-0.11	-0.35	3.07	0.25	0.64	0.31	-15.9	-4.5	39.3	15.1	8.6	3.9	-1.65	-0.12	0.80	1.17	-0.01	0.00
7	5	-0.36	-0.02	2.06	0.38	0.04	0.04	-4.9	-0.5	16.2	5.9	1.0	0.5	-3.66	0.02	1.07	1.15	-0.03	0.00
	10	-0.41	-0.06	2.62	0.46	0.07	0.07	-6.1	-1.0	18.0	7.1	1.9	1.0	-3.35	-0.02	1.05	1.15	-0.02	0.00
	15	-0.53	-0.11	2.93	0.62	0.16	0.11	-7.4	-1.7	19.6	8.1	2.9	1.6	-3.28	-0.03	1.01	1.16	-0.02	0.00
	20	-0.65	-0.18	3.27	0.77	0.28	0.17	-7.9	-2.9	20.1	8.5	4.8	2.6	-3.22	-0.04	0.98	1.16	-0.02	0.00
8	5	-0.14	-0.01	0.78	0.17	0.06	0.02	-2.0	-0.3	9.1	2.6	0.8	0.3	-4.51	0.09	0.84	1.12	-0.02	0.00
	10	-0.15	-0.03	0.84	0.19	0.11	0.03	-2.2	-0.4	9.3	2.7	1.0	0.4	-4.52	0.09	0.81	1.13	-0.01	0.00
	15	-0.17	-0.05	0.90	0.21	0.15	0.05	-2.4	-0.6	9.3	2.8	1.2	0.5	-4.51	0.08	0.80	1.13	-0.01	0.00
	20	-0.18	-0.07	0.87	0.24	0.20	0.06	-2.5	-0.7	9.2	2.9	1.5	0.7	-4.72	0.09	0.78	1.13	-0.01	0.00
9	5	-0.14	-0.06	2.30	0.30	0.15	0.09	-7.7	-0.9	28.0	10.6	1.5	0.9	-6.33	0.22	1.16	1.14	-0.03	0.00
	10	-0.11	-0.13	2.56	0.31	0.27	0.16	-11.8	-1.9	30.4	14.1	2.8	1.8	-6.80	0.25	1.20	1.15	-0.03	0.00
	15	-0.24	-0.26	2.07	0.36	0.52	0.28	-15.0	-4.0	32.3	[illegible]	6.0	3.7	-7.91	0.33	1.20	1.15	-0.03	0.00
	20	-0.44	-0.47	1.95	0.50	0.87	0.47	-22.6	-5.2	41.1	22.1	8.0	5.0	-8.45	0.36	1.20	1.15	-0.03	0.00

TABLE A(III)-26 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.16	-0.04	1.41	0.30	0.12	0.07	-5.0	-0.6	18.5	8.0	1.1	0.7	-7.05	0.30	1.06	1.12	-0.03	0.00
	10	-0.25	-0.08	1.40	0.38	0.21	0.12	-6.7	-1.2	19.3	9.6	1.7	1.3	-7.55	0.34	1.08	1.13	-0.03	0.00
	15	-0.19	-0.16	1.32	0.34	0.33	0.20	-7.8	-2.4	19.6	10.6	2.9	2.3	-7.59	0.33	1.07	1.14	-0.03	0.00
	20	-0.19	-0.30	1.06	0.30	0.54	0.32	-7.0	-4.9	17.6	9.6	5.9	4.5	-8.12	0.37	1.07	1.15	-0.03	0.00
11	5	-0.13	-0.03	1.04	0.33	0.07	0.05	-3.1	-0.5	11.6	5.6	0.8	0.6	-4.66	0.13	0.85	1.11	-0.02	0.00
	10	-0.14	-0.05	1.13	0.37	0.11	0.08	-3.8	-0.8	11.7	6.3	1.0	0.9	-4.58	0.12	0.83	1.12	-0.02	0.00
	15	-0.15	-0.09	1.17	0.41	0.17	0.11	-4.4	-1.3	11.5	6.8	1.4	1.3	-4.72	0.13	0.83	1.13	-0.02	0.00
	20	-0.21	-0.15	1.09	0.46	0.26	0.17	-4.6	-2.1	11.3	7.0	2.1	2.0	-5.11	0.16	0.84	1.13	-0.02	0.00
12	5	-0.11	-0.02	0.89	0.19	0.05	0.02	-1.9	-0.3	8.1	2.8	0.8	0.3	-3.48	0.05	0.84	1.11	-0.02	0.00
	10	-0.13	-0.03	0.87	0.21	0.09	0.04	-2.0	-0.4	8.6	2.9	0.8	0.4	-3.69	0.06	0.82	1.11	-0.01	0.00
	15	-0.14	-0.05	0.91	0.23	0.13	0.05	-2.2	-0.6	8.7	3.0	0.9	0.6	-3.80	0.07	0.81	1.12	-0.01	0.00
	20	-0.14	-0.07	0.92	0.23	0.17	0.07	-2.3	-0.8	8.6	3.1	1.1	0.7	-3.86	0.07	0.80	1.12	-0.01	0.00
13	5	-0.08	-0.02	0.51	0.20	0.05	0.03	-1.5	-0.3	6.0	2.8	0.7	0.4	-4.94	0.16	0.73	1.09	-0.02	0.01
	10	-0.10	-0.03	0.51	0.23	0.07	0.04	-1.7	-0.5	6.3	2.9	0.8	0.5	-5.07	0.17	0.73	1.09	-0.02	0.01
	15	-0.09	-0.05	0.48	0.23	0.11	0.06	-1.8	-0.7	6.3	3.0	0.8	0.7	-5.15	0.17	0.71	1.10	-0.01	0.01
	20	-0.12	-0.07	0.46	0.26	0.15	0.08	-2.0	-0.8	6.0	3.1	1.0	0.8	-5.32	0.18	0.71	1.10	-0.01	0.00
14	5	-0.07	-0.02	0.30	0.19	0.06	0.03	-1.5	-0.4	6.0	2.9	0.8	0.4	-4.30	0.14	0.67	1.09	-0.01	0.01
	10	-0.09	-0.03	0.31	0.22	0.09	0.05	-1.7	-0.5	6.3	3.0	0.8	0.6	-4.40	0.15	0.66	1.09	-0.01	0.01
	15	-0.10	-0.05	0.27	0.23	0.13	0.06	-1.8	-0.7	6.3	3.1	0.9	0.7	-4.43	0.15	0.65	1.10	-0.01	0.01
	20	-0.11	-0.08	0.19	0.24	0.18	0.09	-1.9	-0.9	6.1	3.2	1.0	0.9	-4.51	0.15	0.63	1.11	-0.01	0.00
15	5	-0.07	-0.02	0.23	0.19	0.07	0.03	-1.2	-0.3	5.5	2.6	0.6	0.4	-3.85	0.06	0.61	1.07	0.00	0.01
	10	-0.07	-0.03	0.20	0.19	0.10	0.05	-1.3	-0.5	5.8	2.6	0.7	0.6	-3.93	0.07	0.60	1.08	0.00	0.01
	15	-0.06	-0.05	0.19	0.19	0.13	0.06	-1.2	-0.7	5.8	2.6	0.8	0.7	-3.86	0.06	0.57	1.09	0.01	0.01
	20	-0.05	-0.07	0.19	0.19	0.15	0.08	-1.0	-0.9	5.5	2.5	0.9	0.9	-3.89	0.06	0.57	1.09	0.01	0.01
16	5	-0.07	-0.02	1.35	0.14	0.03	0.02	-1.9	-0.3	10.1	2.5	0.8	0.3	-2.45	-0.10	0.64	1.14	-0.00	0.00
	10	-0.04	-0.03	1.25	0.13	0.09	0.04	-2.2	-0.4	10.1	2.8	0.9	0.3	-2.32	-0.12	0.58	1.14	0.01	0.00
	15	-0.05	-0.05	1.30	0.14	0.13	0.05	-2.5	-0.5	10.2	3.0	1.0	0.4	-2.34	-0.12	0.57	1.15	0.01	0.00
	20	-0.08	-0.07	1.12	0.16	0.20	0.06	-2.7	-0.6	10.1	3.1	1.2	0.5	-2.49	-0.12	0.53	1.15	0.01	0.00
17	5	-0.07	-0.01	0.42	0.10	0.10	0.02	-1.4	-0.2	9.0	1.9	0.7	0.2	-4.81	0.01	0.58	1.13	0.00	0.00
	10	-0.06	-0.03	0.40	0.10	0.14	0.03	-1.7	-0.3	9.0	2.1	0.8	0.3	-4.54	-0.02	0.51	1.14	0.01	0.00
	15	-0.07	-0.04	0.36	0.11	0.19	0.04	-1.9	-0.4	8.9	2.2	1.0	0.3	-4.70	-0.01	0.49	1.14	0.01	0.00
	20	-0.09	-0.06	0.37	0.13	0.24	0.05	-2.0	-0.5	8.7	2.3	1.1	0.4	-4.85	-0.01	0.48	1.14	0.01	0.00
18	5	-0.09	-0.02	0.36	0.14	0.07	0.02	-1.5	-0.3	6.3	2.1	0.7	0.3	-5.08	0.12	0.68	1.10	-0.01	0.00
	10	-0.09	-0.03	0.35	0.16	0.11	0.03	-1.6	-0.3	6.6	2.2	0.8	0.3	-5.04	0.12	0.65	1.11	-0.00	0.00
	15	-0.11	-0.04	0.35	0.18	0.14	0.04	-1.8	-0.4	6.8	2.3	0.8	0.4	-5.06	0.12	0.63	1.11	-0.00	0.00
	20	-0.13	-0.05	0.29	0.19	0.18	0.05	-1.9	-0.5	6.8	2.4	0.8	0.5	-5.14	0.12	0.61	1.12	-0.00	0.00

TABLE A(III)-26 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.10	-0.02	0.25	0.19	0.07	0.03	-1.7	-0.3	6.7	2.7	0.7	0.3	-4.59	0.15	0.71	1.10	-0.01	0.00
	10	-0.12	-0.03	0.22	0.21	0.12	0.04	-1.9	-0.4	7.0	2.9	0.7	0.4	-4.78	0.16	0.70	1.10	-0.01	0.00
	15	-0.14	-0.05	0.22	0.24	0.15	0.05	-2.1	-0.5	7.0	3.0	0.8	0.5	-4.86	0.17	0.69	1.11	-0.01	0.00
	20	-0.17	-0.06	0.20	0.26	0.19	0.07	-2.3	-0.7	6.9	3.1	0.9	0.6	-4.93	0.17	0.67	1.11	-0.01	0.00
20	5	-0.08	-0.02	0.31	0.19	0.07	0.03	-1.7	-0.3	7.2	2.9	0.7	0.4	-4.12	0.10	0.62	1.10	-0.01	0.00
	10	-0.08	-0.03	0.31	0.21	0.11	0.04	-1.9	-0.5	7.4	3.0	0.7	0.5	-4.16	0.11	0.59	1.11	-0.00	0.00
	15	-0.09	-0.05	0.28	0.22	0.15	0.06	-2.0	-0.6	7.3	3.1	0.8	0.6	-4.18	0.10	0.57	1.11	-0.00	0.00
	20	-0.10	-0.07	0.22	0.24	0.19	0.08	-2.2	-0.8	7.0	3.2	1.0	0.8	-4.31	0.11	0.55	1.12	0.00	0.00
21	5	-0.08	-0.02	0.29	0.18	0.08	0.03	-1.4	-0.3	6.5	2.7	0.6	0.4	-3.86	0.09	0.63	1.09	-0.00	0.01
	10	-0.09	-0.03	0.34	0.21	0.10	0.04	-1.4	-0.5	6.5	2.8	0.7	0.5	-3.94	0.10	0.62	1.09	-0.00	0.01
	15	-0.09	-0.05	0.34	0.22	0.13	0.06	-1.4	-0.6	6.3	2.8	0.8	0.7	-3.94	0.10	0.60	1.10	-0.00	0.00
	20	-0.10	-0.07	0.37	0.23	0.16	0.08	-1.4	-0.8	6.1	2.8	0.9	0.8	-3.93	0.09	0.59	1.11	0.00	0.00
25	5	-0.11	-0.01	0.40	0.17	0.07	0.02	-1.5	-0.3	6.8	2.4	0.6	0.3	-4.71	0.12	0.76	1.10	-0.01	0.00
	10	-0.13	-0.02	0.45	0.19	0.10	0.03	-1.7	-0.4	6.6	2.5	0.8	0.4	-4.83	0.12	0.75	1.11	-0.01	0.00
	15	-0.15	-0.04	0.49	0.21	0.13	0.05	-1.8	-0.5	6.4	2.6	0.9	0.5	-4.96	0.13	0.76	1.11	-0.01	0.00
	20	-0.18	-0.05	0.54	0.24	0.16	0.06	-1.9	-0.6	6.4	2.7	1.0	0.6	-5.14	0.14	0.78	1.11	-0.01	0.00
26	5	-0.15	-0.01	0.48	0.19	0.06	0.03	-1.6	-0.3	6.6	3.0	0.7	0.4	-5.16	0.14	1.08	1.07	-0.03	0.01
	10	-0.18	-0.03	0.57	0.22	0.09	0.04	-1.7	-0.5	7.2	3.1	0.8	0.6	-5.21	0.14	1.08	1.08	-0.02	0.01
	15	-0.19	-0.04	0.59	0.23	0.12	0.06	-1.8	-0.7	7.4	3.1	0.9	0.7	-5.47	0.16	1.08	1.09	-0.02	0.01
	20	-0.19	-0.06	0.63	0.24	0.16	0.08	-1.8	-0.9	7.5	3.0	1.0	0.9	-5.62	0.17	1.08	1.10	-0.02	0.01
27	5	-0.13	-0.02	0.85	0.23	0.05	0.04	-1.8	-0.4	6.6	3.9	0.9	0.6	-3.85	0.00	1.01	1.10	-0.02	0.00
	10	-0.13	-0.04	0.96	0.25	0.08	0.07	-1.8	-0.7	7.4	3.9	1.1	0.8	-3.76	-0.00	1.01	1.11	-0.01	0.00
	15	-0.09	-0.07	0.99	0.24	0.12	0.10	-1.7	-1.0	8.0	3.8	1.3	1.1	-3.79	-0.00	1.01	1.11	-0.01	0.00
	20	-0.05	-0.11	1.00	0.21	0.17	0.14	-1.5	-1.4	8.5	3.6	1.4	1.4	-3.96	0.01	1.03	1.12	-0.01	0.00

TABLE A(III)-27. SOYBEANS, NO TILLAGE, FALL FERTILIZATION (A,B,C,D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.18	-0.03	0.97	0.28	0.40	0.05	-4.4	-0.4	34.1	6.2	2.0	0.4	-1.33	-0.02	0.00	1.16	0.00	0.00
	10	-0.19	-0.08	2.33	0.31	0.47	0.09	-5.8	-0.7	40.5	7.5	2.9	0.7	-1.32	-0.02	0.00	1.17	0.00	0.00
	15	-0.33	-0.13	4.02	0.45	0.54	0.14	-7.3	-1.3	45.9	8.8	4.2	1.2	-1.48	-0.00	0.01	1.17	0.00	0.00
	20	-0.51	-0.20	5.07	0.64	0.71	0.20	-8.7	-2.8	49.8	9.9	7.2	2.4	-1.52	0.00	0.01	1.17	0.00	0.00
2	5	-0.04	-0.03	3.74	0.09	0.11	0.04	-2.6	-0.4	26.0	3.6	2.1	0.4	-0.35	-0.15	0.01	1.17	0.00	-0.00
	10	-0.07	-0.06	4.62	0.13	0.14	0.06	-3.2	-0.7	28.8	4.1	3.1	0.6	-0.24	-0.16	0.01	1.17	0.01	-0.00
	15	-0.14	-0.09	5.55	0.21	0.18	0.09	-3.7	-1.1	30.6	4.4	4.1	1.0	-0.03	-0.18	0.01	1.17	0.01	-0.00
	20	-0.26	-0.12	6.07	0.33	0.27	0.11	-3.8	-1.8	30.9	4.4	5.5	1.4	-0.07	-0.17	0.01	1.17	0.01	0.00
3	5	-0.02	-0.01	0.97	0.04	0.19	0.02	-0.8	-0.1	13.9	1.3	1.3	0.2	-0.95	-0.13	0.00	1.15	0.00	0.00
	10	-0.00	-0.02	1.25	0.03	0.20	0.02	-0.9	-0.2	14.5	1.4	1.6	0.2	-0.84	-0.15	0.00	1.16	0.00	0.00
	15	0.00	-0.03	1.43	0.02	0.22	0.03	-0.9	-0.3	14.8	1.4	1.6	0.2	-0.83	-0.15	0.00	1.16	0.00	0.00
	20	0.02	-0.04	1.66	0.02	0.24	0.04	-1.0	-0.3	15.0	1.5	1.7	0.3	-0.77	-0.16	0.01	1.16	0.00	0.00
4	5	-0.15	-0.01	0.57	0.20	0.27	0.02	-2.0	-0.3	18.4	3.0	1.8	0.3	-2.54	-0.03	0.03	1.14	0.00	0.00
	10	-0.15	-0.03	0.99	0.21	0.31	0.04	-2.2	-0.5	20.2	3.3	2.5	0.5	-2.35	-0.05	0.04	1.15	0.00	0.00
	15	-0.14	-0.06	1.43	0.22	0.36	0.06	-2.4	-0.7	21.6	3.5	3.1	0.7	-2.39	-0.05	0.05	1.15	0.00	0.00
	20	-0.14	-0.08	1.96	0.25	0.40	0.09	-2.3	-1.1	21.6	3.4	4.0	1.0	-2.39	-0.05	0.06	1.16	0.00	0.00
5	5	-0.02	-0.02	1.16	0.06	0.18	0.03	-1.3	-0.2	15.3	2.2	1.5	0.3	-2.08	-0.18	0.06	1.15	0.00	0.00
	10	-0.00	-0.03	1.52	0.06	0.20	0.04	-1.5	-0.3	16.2	2.4	2.0	0.4	-1.95	-0.20	0.06	1.16	0.00	0.00
	15	0.02	-0.04	1.92	0.06	0.21	0.05	-1.5	-0.4	16.8	2.4	2.4	0.5	-1.87	-0.21	0.07	1.16	0.00	0.00
	20	0.02	-0.06	2.19	0.06	0.23	0.07	-1.5	-0.6	17.2	2.5	2.9	0.6	-1.97	-0.21	0.07	1.16	0.00	0.00
6	5	-0.35	-0.03	-0.66	0.37	0.47	0.05	-6.0	-0.5	35.9	8.0	2.3	0.6	-3.68	0.07	-0.01	1.15	0.00	0.00
	10	-0.26	-0.09	-0.28	0.34	0.64	0.11	-8.4	-1.1	44.3	10.5	3.9	1.1	-2.64	-0.03	-0.01	1.16	0.00	0.00
	15	-0.20	-0.17	-0.00	0.30	0.87	0.19	-11.1	-2.2	51.4	12.8	5.8	2.1	-2.55	-0.03	-0.01	1.16	0.00	0.00
	20	-0.10	-0.30	0.41	0.25	1.13	0.30	-13.5	-4.3	56.6	14.7	9.4	3.9	-1.65	-0.12	-0.01	1.17	0.00	0.00
7	5	-0.31	-0.02	0.85	0.37	0.25	0.04	-4.0	-0.4	21.8	5.7	1.7	0.5	-3.66	0.02	0.06	1.15	0.00	0.00
	10	-0.36	-0.05	1.48	0.46	0.30	0.07	-5.0	-0.9	25.7	6.8	2.9	1.0	-3.35	-0.02	0.07	1.15	-0.00	0.00
	15	-0.47	-0.09	2.62	0.61	0.32	0.11	-6.0	-1.5	29.3	7.9	4.0	1.5	-3.28	-0.03	0.08	1.16	-0.00	0.00
	20	-0.58	-0.15	3.49	0.75	0.39	0.16	-6.3	-2.8	31.1	8.2	5.8	2.6	-3.22	-0.04	0.09	1.16	-0.00	0.00
8	5	-0.11	-0.01	1.11	0.16	0.12	0.02	-1.5	-0.2	12.4	2.5	1.2	0.3	-4.51	0.09	0.15	1.12	-0.01	0.00
	10	-0.13	-0.02	1.35	0.19	0.13	0.03	-1.7	-0.3	13.2	2.6	1.7	0.4	-4.52	0.09	0.16	1.13	-0.01	0.00
	15	-0.14	-0.04	1.54	0.21	0.16	0.05	-1.8	-0.5	13.6	2.7	2.1	0.5	-4.51	0.08	0.16	1.13	-0.01	0.00
	20	-0.15	-0.05	1.79	0.23	0.17	0.06	-1.8	-0.6	13.7	2.8	2.5	0.6	-4.72	0.09	0.17	1.13	-0.01	0.00
9	5	-0.13	-0.05	-0.47	0.30	0.39	0.09	-6.7	-0.7	33.2	10.5	2.3	0.9	-6.33	0.22	0.00	1.14	0.00	0.00
	10	-0.10	-0.12	-0.46	0.30	0.57	0.15	-10.3	-1.7	39.1	13.8	3.8	1.8	-6.80	0.25	0.00	1.15	0.00	0.00
	15	-0.21	-0.24	-0.47	0.35	0.84	0.28	-13.6	-3.9	40.4	16.0	6.4	3.7	-7.91	0.33	0.01	1.15	0.00	0.00
	20	-0.39	-0.45	-0.18	0.49	1.17	0.46	-21.3	-5.1	48.3	21.9	7.5	4.9	-8.45	0.36	0.01	1.15	0.00	0.00

TABLE A(III)-27 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.16	-0.03	0.53	0.30	0.22	0.07	-4.4	-0.5	21.6	7.9	1.8	0.7	-7.05	0.30	0.08	1.12	0.00	0.00
	10	-0.23	-0.07	0.61	0.38	0.34	0.11	-5.8	-1.1	25.4	9.5	2.5	1.2	-7.55	0.34	0.09	1.13	-0.00	0.00
	15	-0.17	-0.15	0.32	0.33	0.51	0.20	-6.7	-2.3	27.1	10.4	3.8	2.2	-7.59	0.33	0.06	1.14	0.00	0.00
	20	-0.16	-0.27	-0.17	0.29	0.74	0.32	-5.9	-4.8	25.2	9.4	6.5	4.5	-8.12	0.37	0.03	1.15	0.01	0.00
11	5	-0.12	-0.02	1.01	0.33	0.11	0.05	-2.8	-0.4	13.3	5.5	1.2	0.6	-4.66	0.13	0.20	1.11	-0.01	0.00
	10	-0.13	-0.05	1.08	0.37	0.16	0.07	-3.2	-0.7	15.1	6.2	1.7	0.9	-4.58	0.12	0.20	1.12	-0.01	0.00
	15	-0.14	-0.08	1.22	0.41	0.21	0.11	-3.6	-1.2	16.3	6.7	2.3	1.3	-4.72	0.13	0.21	1.13	-0.01	0.00
	20	-0.18	-0.13	1.44	0.46	0.27	0.17	-3.8	-1.9	17.0	6.8	3.0	1.9	-5.11	0.16	0.23	1.13	-0.01	0.00
12	5	-0.10	-0.01	0.42	0.19	0.13	0.02	-1.6	-0.3	10.1	2.7	1.0	0.3	-3.48	0.05	0.08	1.11	0.00	0.00
	10	-0.12	-0.03	0.51	0.21	0.15	0.04	-1.7	-0.4	10.7	2.9	1.4	0.4	-3.69	0.06	0.09	1.11	0.00	0.00
	15	-0.13	-0.04	0.57	0.23	0.18	0.05	-1.8	-0.5	11.1	3.0	1.7	0.6	-3.80	0.07	0.09	1.12	0.00	0.00
	20	-0.12	-0.06	0.69	0.23	0.21	0.07	-1.9	-0.7	11.4	3.0	2.0	0.7	-3.86	0.07	0.10	1.12	0.00	0.00
13	5	-0.07	-0.01	0.90	0.20	0.07	0.03	-1.3	-0.3	7.6	2.7	0.9	0.4	-4.94	0.16	0.33	1.09	-0.01	0.01
	10	-0.09	-0.02	0.99	0.23	0.09	0.04	-1.4	-0.4	8.0	2.9	1.2	0.5	-5.07	0.17	0.33	1.09	-0.01	0.01
	15	-0.09	-0.04	1.09	0.23	0.10	0.06	-1.5	-0.6	8.4	2.9	1.4	0.7	-5.15	0.17	0.35	1.10	-0.01	0.01
	20	-0.10	-0.06	1.13	0.25	0.13	0.08	-1.5	-0.7	8.7	3.0	1.7	0.8	-5.32	0.18	0.35	1.10	-0.01	0.00
14	5	-0.07	-0.02	1.04	0.19	0.06	0.03	-1.3	-0.3	7.6	2.8	0.9	0.4	-4.30	0.14	0.41	1.09	-0.02	0.01
	10	-0.08	-0.03	1.14	0.22	0.07	0.04	-1.4	-0.5	8.0	3.0	1.2	0.6	-4.40	0.15	0.43	1.09	-0.02	0.01
	15	-0.09	-0.05	1.19	0.23	0.10	0.06	-1.5	-0.6	8.2	3.1	1.5	0.7	-4.43	0.15	0.44	1.10	-0.02	0.01
	20	-0.09	-0.07	1.27	0.24	0.12	0.08	-1.5	-0.8	8.5	3.1	1.7	0.9	-4.51	0.15	0.45	1.11	-0.02	0.00
15	5	-0.07	-0.02	0.50	0.19	0.07	0.03	-1.1	-0.3	5.8	2.6	0.9	0.4	-3.85	0.06	0.17	1.07	-0.00	0.01
	10	-0.06	-0.03	0.55	0.19	0.09	0.05	-1.2	-0.4	6.0	2.6	1.1	0.6	-3.93	0.07	0.18	1.08	-0.00	0.01
	15	-0.05	-0.04	0.56	0.19	0.11	0.06	-1.1	-0.6	6.1	2.6	1.3	0.7	-3.86	0.06	0.17	1.09	-0.00	0.01
	20	-0.04	-0.06	0.55	0.19	0.14	0.08	-0.9	-0.8	6.2	2.5	1.6	0.9	-3.89	0.06	0.16	1.09	-0.00	0.01
16	5	-0.07	-0.01	1.39	0.14	0.14	0.02	-1.3	-0.2	13.9	2.4	1.2	0.3	-2.45	-0.10	0.15	1.14	0.00	0.00
	10	-0.05	-0.03	1.82	0.13	0.14	0.04	-1.5	-0.3	15.0	2.6	1.5	0.3	-2.32	-0.12	0.17	1.14	-0.00	0.00
	15	-0.05	-0.04	2.04	0.14	0.16	0.05	-1.7	-0.4	15.9	2.8	1.7	0.4	-2.34	-0.12	0.18	1.15	-0.00	0.00
	20	-0.07	-0.05	2.36	0.16	0.16	0.06	-1.8	-0.5	16.4	2.9	2.0	0.5	-2.49	-0.12	0.19	1.15	-0.00	0.00
17	5	-0.06	-0.01	1.21	0.10	0.13	0.02	-1.0	-0.1	12.0	1.8	1.1	0.2	-4.81	0.01	0.21	1.13	-0.00	0.00
	10	-0.05	-0.02	1.57	0.10	0.14	0.03	-1.1	-0.2	12.9	2.0	1.4	0.3	-4.54	-0.02	0.24	1.14	-0.01	0.00
	15	-0.06	-0.03	1.84	0.11	0.14	0.04	-1.2	-0.3	13.6	2.1	1.6	0.3	-4.70	-0.01	0.25	1.14	-0.01	0.00
	20	-0.07	-0.04	2.09	0.13	0.15	0.05	-1.2	-0.4	14.1	2.1	1.9	0.4	-4.85	-0.01	0.26	1.14	-0.01	0.00
18	5	-0.08	-0.01	1.56	0.14	0.04	0.02	-1.1	-0.2	8.7	2.1	0.9	0.3	-5.08	0.12	0.37	1.10	-0.02	0.00
	10	-0.09	-0.02	1.78	0.16	0.04	0.03	-1.2	-0.3	9.2	2.2	1.2	0.3	-5.04	0.12	0.40	1.11	-0.02	0.00
	15	-0.10	-0.03	1.92	0.17	0.05	0.04	-1.3	-0.3	9.6	2.2	1.3	0.4	-5.06	0.12	0.41	1.11	-0.02	0.00
	20	-0.11	-0.04	2.10	0.19	0.05	0.05	-1.4	-0.4	9.9	2.3	1.5	0.5	-5.14	0.12	0.42	1.12	-0.02	0.00

TABLE A(III)-27 (CONT)

REGION	AW	AO	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
19	5	-0.09	-0.01	1.58	0.19	0.04	0.03	-1.4	-0.3	8.8	2.7	0.9	0.3	-4.59	0.15	0.44	1.10	-0.02	0.00
	10	-0.11	-0.03	1.78	0.21	0.04	0.04	-1.5	-0.4	9.4	2.8	1.2	0.4	-4.78	0.16	0.46	1.10	-0.02	0.00
	15	-0.12	-0.04	1.90	0.23	0.05	0.05	-1.7	-0.5	9.9	2.9	1.4	0.5	-4.86	0.17	0.48	1.11	-0.02	0.00
	20	-0.14	-0.05	1.97	0.25	0.07	0.07	-1.8	-0.6	10.2	3.0	1.6	0.6	-4.93	0.17	0.48	1.11	-0.02	0.00
20	5	-0.07	-0.02	1.07	0.19	0.06	0.03	-1.5	-0.3	8.4	2.8	0.9	0.4	-4.12	0.10	0.33	1.10	-0.01	0.00
	10	-0.08	-0.03	1.22	0.21	0.08	0.04	-1.6	-0.4	8.8	3.0	1.2	0.5	-4.16	0.11	0.34	1.11	-0.01	0.00
	15	-0.08	-0.05	1.31	0.22	0.10	0.06	-1.7	-0.5	9.2	3.1	1.5	0.6	-4.18	0.10	0.35	1.11	-0.02	0.00
	20	-0.09	-0.06	1.43	0.23	0.11	0.08	-1.7	-0.7	9.7	3.2	1.7	0.8	-4.31	0.11	0.36	1.12	-0.02	0.00
21	5	-0.07	-0.02	0.80	0.18	0.07	0.03	-1.3	-0.3	7.0	2.7	0.9	0.4	-3.86	0.09	0.27	1.09	-0.01	0.01
	10	-0.09	-0.03	0.87	0.20	0.09	0.04	-1.3	-0.4	7.3	2.7	1.2	0.5	-3.94	0.10	0.28	1.09	-0.01	0.01
	15	-0.09	-0.04	0.91	0.22	0.11	0.06	-1.2	-0.6	7.6	2.8	1.4	0.7	-3.94	0.10	0.28	1.10	-0.01	0.00
	20	-0.10	-0.06	0.97	0.23	0.13	0.08	-1.1	-0.7	7.7	2.8	1.7	0.8	-3.93	0.09	0.28	1.11	-0.01	0.00
25	5	-0.10	-0.01	0.85	0.16	0.10	0.02	-1.2	-0.2	9.1	2.3	1.0	0.3	-4.71	0.12	0.18	1.10	-0.00	0.00
	10	-0.11	-0.02	1.00	0.19	0.11	0.03	-1.3	-0.3	9.6	2.4	1.3	0.4	-4.83	0.12	0.19	1.11	-0.00	0.00
	15	-0.12	-0.03	1.12	0.21	0.12	0.04	-1.3	-0.4	9.9	2.5	1.5	0.5	-4.96	0.13	0.20	1.11	-0.00	0.00
	20	-0.15	-0.04	1.22	0.24	0.13	0.06	-1.3	-0.5	10.2	2.5	1.8	0.6	-5.14	0.14	0.21	1.11	-0.00	0.00
26	5	-0.14	-0.01	0.15	0.19	0.11	0.03	-1.4	-0.3	7.6	2.9	0.9	0.4	-5.16	0.14	0.05	1.07	0.00	0.01
	10	-0.16	-0.02	0.16	0.22	0.13	0.04	-1.5	-0.4	7.8	3.0	1.3	0.6	-5.21	0.14	0.05	1.08	-0.00	0.01
	15	-0.16	-0.04	0.15	0.23	0.15	0.06	-1.6	-0.6	7.7	3.0	1.6	0.7	-5.47	0.16	0.05	1.09	-0.00	0.01
	20	-0.17	-0.06	0.12	0.24	0.18	0.08	-1.6	-0.8	8.0	3.0	1.7	0.9	-5.62	0.17	0.05	1.10	-0.00	0.01
27	5	-0.12	-0.02	0.18	0.23	0.10	0.04	-1.6	-0.4	8.2	3.8	1.1	0.6	-3.85	0.00	0.03	1.10	0.00	0.00
	10	-0.11	-0.04	0.17	0.25	0.15	0.07	-1.6	-0.6	8.2	3.9	1.5	0.8	-3.76	-0.00	0.02	1.11	0.00	0.00
	15	-0.08	-0.07	0.16	0.24	0.20	0.10	-1.6	-0.9	8.1	3.8	2.0	1.1	-3.79	-0.00	0.02	1.11	0.00	0.00
	20	-0.04	-0.11	0.03	0.21	0.26	0.14	-1.4	-1.3	8.5	3.6	2.1	1.4	-3.96	0.01	0.01	1.12	0.00	0.00

TABLE A(III)-28. FALL PLOW SOYBEANS (A SOILS ONLY)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	0.69	0.92	-0.63	47.86	10	5	1.45	0.72	-1.38	54.00	19	5	1.13	6.61	-1.10	61.52
	10	0.62	0.94	-0.51	36.11		10	1.41	0.70	-1.14	39.60		10	1.13	6.45	-1.04	54.46
	15	0.57	0.86	-0.43	27.45		15	1.33	0.60	-1.01	30.73		15	1.10	6.34	-0.97	49.50
	20	0.51	0.90	-0.38	19.86		20	1.28	0.58	-0.90	23.35		20	1.08	6.17	-0.95	45.53
2	5	1.09	2.84	-1.05	51.16	11	5	1.31	2.93	-1.26	60.02	20	5	1.16	7.09	-1.13	61.63
	10	1.02	2.92	-0.93	40.87		10	1.25	2.94	-1.04	47.42		10	1.17	6.93	-1.06	53.08
	15	0.96	2.94	-0.82	33.33		15	1.23	2.75	-0.91	39.46		15	1.16	6.80	-0.98	47.29
	20	0.89	3.08	-0.75	27.67		20	1.20	2.57	-0.82	33.10		20	1.12	6.68	-0.88	42.44
3	5	1.50	4.76	-1.49	63.32	12	5	1.70	2.62	-1.67	64.49	21	5	1.37	7.86	-1.35	61.98
	10	1.54	4.51	-1.53	57.81		10	1.76	2.39	-1.68	56.17		10	1.41	7.61	-1.32	53.80
	15	1.54	4.43	-1.54	54.60		15	1.79	2.22	-1.64	50.47		15	1.40	7.41	-1.26	48.20
	20	1.53	4.30	-1.53	51.95		20	1.79	1.98	-1.58	45.84		20	1.38	7.26	-1.22	43.88
4	5	1.60	0.92	-1.57	58.45	13	5	1.23	9.18	-1.19	62.53	25	5	1.52	4.33	-1.50	66.85
	10	1.63	0.66	-1.53	49.01		10	1.22	9.15	-1.08	53.91		10	1.53	4.26	-1.48	59.39
	15	1.60	0.58	-1.44	42.32		15	1.20	9.02	-0.95	48.06		15	1.55	4.09	-1.50	54.34
	20	1.56	0.47	-1.44	37.24		20	1.18	8.84	-0.85	43.42		20	1.55	3.94	-1.49	50.39
5	5	1.54	2.65	-1.52	59.92	14	5	1.06	9.78	-1.02	60.24	26	5	2.23	1.69	-2.21	66.01
	10	1.57	2.51	-1.49	52.17		10	1.07	9.57	-0.90	51.46		10	2.30	1.32	-2.25	57.82
	15	1.56	2.36	-1.49	46.98		15	1.06	9.39	-0.80	45.71		15	2.35	0.95	-2.30	53.27
	20	1.56	2.24	-1.48	42.68		20	1.01	9.20	-0.71	41.13		20	2.36	0.82	-2.32	49.71
6	5	1.12	-1.05	-1.03	45.17	15	5	1.78	7.27	-1.76	62.09	27	5	2.58	-0.48	-2.56	62.80
	10	1.06	-1.14	-0.81	31.12		10	1.82	6.92	-1.75	54.38		10	2.66	-0.93	-2.61	54.08
	15	0.98	-1.06	-0.65	22.50		15	1.84	6.63	-1.76	49.77		15	2.74	-1.43	-2.63	48.67
	20	0.91	-0.97	-0.58	16.09		20	1.84	6.42	-1.77	46.26		20	2.79	-1.82	-2.66	44.56
7	5	1.60	-1.46	-1.53	53.32	16	5	1.12	4.58	-1.09	61.28						
	10	1.64	-1.74	-1.41	40.18		10	1.10	4.42	-1.02	53.95						
	15	1.61	-1.91	-1.22	31.41		15	1.08	4.37	-0.97	48.55						
	20	1.57	-1.93	-1.08	24.52		20	1.07	4.23	-0.98	44.64						
8	5	1.62	2.31	-1.58	61.99	17	5	1.34	3.70	-1.32	63.41						
	10	1.68	2.04	-1.59	54.05		10	1.36	3.51	-1.30	56.45						
	15	1.70	1.85	-1.56	48.65		15	1.34	3.40	-1.28	51.53						
	20	1.70	1.62	-1.56	44.58		20	1.34	3.31	-1.27	47.25						
9	5	1.49	-1.61	-1.37	45.60	18	5	0.95	7.82	-0.94	64.26						
	10	1.39	-1.65	-1.03	30.01		10	0.94	7.70	-0.90	57.76						
	15	1.33	-1.64	-0.95	21.64		15	0.92	7.60	-0.86	53.05						
	20	1.26	-1.56	-0.90	15.20		20	0.90	7.45	-0.86	49.12						

TABLE A(III)-29. FALL PLOW SOYBEANS, SPRING FERTILIZATION (A SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.02	-0.07	2.23	0.26	0.13	0.05	-7.0	-0.1	29.3	7.6	0.3	0.1	0.14	-0.30	0.31	1.17	0.06	-0.00
	10	-0.23	-0.10	2.48	0.47	0.24	0.07	-9.8	-0.1	33.6	9.8	0.3	0.1	0.18	-0.31	0.27	1.17	0.06	-0.00
	15	-0.60	-0.11	2.89	0.77	0.35	0.08	-13.4	-0.2	39.6	12.6	0.4	0.2	0.15	-0.31	0.24	1.18	0.07	-0.00
	20	-1.17	-0.12	4.11	1.24	0.40	0.09	-19.0	-0.4	50.3	17.0	0.7	0.3	0.12	-0.30	0.23	1.18	0.07	-0.00
2	5	0.05	-0.06	0.54	0.04	0.19	0.05	-4.9	-0.1	24.5	4.9	0.4	0.1	0.31	-0.31	0.03	1.18	0.08	-0.00
	10	-0.04	-0.08	0.70	0.14	0.28	0.06	-6.7	-0.2	27.7	6.2	0.4	0.1	0.33	-0.31	0.02	1.18	0.08	-0.00
	15	-0.22	-0.10	0.96	0.28	0.36	0.07	-8.8	-0.2	30.6	7.5	0.5	0.2	0.38	-0.32	-0.01	1.18	0.08	-0.00
	20	-0.46	-0.10	1.55	0.47	0.40	0.08	-10.9	-0.3	33.8	9.0	0.7	0.2	0.37	-0.31	-0.01	1.18	0.07	-0.00
3	5	0.03	-0.03	0.46	0.02	0.10	0.02	-1.9	-0.1	13.3	1.9	0.3	0.1	0.11	-0.34	0.07	1.17	0.07	-0.00
	10	0.04	-0.04	0.41	0.02	0.15	0.03	-2.2	-0.1	13.6	2.1	0.3	0.1	0.18	-0.35	0.05	1.17	0.07	-0.00
	15	0.04	-0.05	0.38	0.03	0.19	0.03	-2.5	-0.1	13.6	2.2	0.3	0.1	0.19	-0.36	0.04	1.17	0.07	-0.00
	20	0.03	-0.06	0.34	0.04	0.23	0.04	-2.8	-0.1	13.7	2.3	0.3	0.1	0.23	-0.37	0.02	1.17	0.08	-0.00
4	5	0.05	-0.05	1.06	0.12	0.11	0.03	-3.6	-0.1	16.5	4.0	0.4	0.1	-0.30	-0.37	0.29	1.17	0.07	-0.00
	10	0.02	-0.07	1.06	0.18	0.18	0.04	-4.5	-0.2	18.1	4.7	0.5	0.2	-0.19	-0.39	0.26	1.17	0.07	-0.00
	15	-0.04	-0.08	1.14	0.25	0.23	0.05	-5.4	-0.2	19.6	5.4	0.6	0.2	-0.15	-0.40	0.23	1.17	0.07	-0.00
	20	-0.14	-0.09	1.33	0.36	0.29	0.06	-6.3	-0.3	20.8	6.0	0.8	0.3	-0.11	-0.41	0.20	1.17	0.08	-0.00
5	5	0.10	-0.04	0.39	0.04	0.12	0.03	-2.6	-0.1	13.9	3.0	0.3	0.1	-0.39	-0.50	0.13	1.17	0.07	-0.00
	10	0.11	-0.06	0.36	0.06	0.19	0.04	-3.3	-0.1	14.7	3.5	0.4	0.1	-0.33	-0.51	0.11	1.17	0.07	-0.00
	15	0.09	-0.07	0.32	0.09	0.24	0.05	-3.8	-0.2	15.3	3.8	0.4	0.1	-0.28	-0.53	0.09	1.17	0.08	-0.00
	20	0.06	-0.09	0.36	0.12	0.29	0.06	-4.4	-0.2	15.8	4.2	0.5	0.2	-0.31	-0.54	0.09	1.17	0.08	-0.00
6	5	-0.20	-0.06	1.59	0.46	0.21	0.03	-8.8	-0.3	28.4	9.4	0.5	0.3	-0.49	-0.39	0.25	1.17	0.08	-0.00
	10	-0.51	-0.07	1.99	0.84	0.30	0.03	-13.1	-0.4	35.7	13.2	0.8	0.4	0.11	-0.45	0.12	1.17	0.09	-0.00
	15	-1.09	-0.07	2.83	1.39	0.36	0.02	-18.5	-0.7	45.4	17.7	1.2	0.6	0.20	-0.46	0.07	1.18	0.10	-0.00
	20	-1.94	-0.05	4.55	2.16	0.34	0.00	-25.6	-1.2	58.5	23.4	2.1	1.1	0.36	-0.48	0.06	1.18	0.10	-0.00
7	5	-0.13	-0.05	1.14	0.42	0.15	0.03	-5.8	-0.2	18.2	6.8	0.5	0.3	-1.43	-0.31	0.40	1.16	0.07	-0.00
	10	-0.35	-0.06	1.41	0.70	0.21	0.03	-8.0	-0.4	21.6	8.8	0.7	0.4	-1.26	-0.33	0.36	1.17	0.07	-0.00
	15	-0.76	-0.06	1.93	1.15	0.24	0.02	-10.5	-0.6	25.3	11.0	1.0	0.6	-1.20	-0.34	0.31	1.17	0.08	-0.00
	20	-1.27	-0.05	2.74	1.65	0.27	0.01	-13.5	-1.0	30.0	13.6	1.5	0.9	-1.20	-0.35	0.30	1.17	0.08	-0.00
8	5	0.02	-0.04	0.42	0.12	0.11	0.03	-2.8	-0.1	11.2	3.3	0.2	0.1	-1.70	-0.34	0.30	1.15	0.06	-0.00
	10	-0.01	-0.05	0.42	0.17	0.16	0.03	-3.3	-0.1	12.0	3.7	0.3	0.1	-1.68	-0.34	0.29	1.15	0.06	-0.00
	15	-0.05	-0.06	0.43	0.23	0.21	0.04	-3.8	-0.2	12.7	4.1	0.3	0.2	-1.65	-0.35	0.28	1.16	0.07	-0.00
	20	-0.11	-0.07	0.46	0.29	0.25	0.05	-4.3	-0.2	13.2	4.5	0.4	0.2	-1.68	-0.35	0.26	1.16	0.07	-0.00
9	5	-0.46	-0.06	0.24	0.84	0.30	0.01	-11.7	-0.5	24.8	13.0	0.9	0.6	-8.14	0.08	0.82	1.15	0.02	0.00
	10	-0.92	-0.06	0.96	1.30	0.34	0.01	-18.6	-1.0	34.8	19.1	1.5	1.0	-8.87	0.16	0.89	1.15	0.02	0.00
	15	-1.69	-0.06	2.06	2.01	0.36	0.01	-25.7	-1.9	44.2	25.0	2.7	1.8	-9.42	0.20	0.93	1.16	0.01	0.00
	20	-2.74	-0.08	3.66	2.92	0.39	0.03	-32.7	-3.1	53.9	30.5	4.4	2.9	-9.67	0.21	0.96	1.16	0.01	0.00

TABLE A(III)-29 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.27	-0.05	-0.09	0.71	0.25	0.01	-8.1	-0.3	16.5	10.2	0.4	0.3	-7.62	0.09	0.72	1.14	0.02	0.00
	10	-0.56	-0.06	0.22	1.06	0.29	0.01	-11.7	-0.5	21.4	13.7	0.6	0.5	-7.77	0.12	0.74	1.15	0.02	0.00
	15	-0.91	-0.07	0.70	1.40	0.33	0.62	-15.8	-0.8	26.4	17.4	0.9	0.8	-7.97	0.15	0.75	1.15	0.02	0.00
	20	-1.40	-0.08	1.44	1.85	0.36	0.04	-21.2	-1.3	32.8	22.2	1.5	1.3	-8.12	0.16	0.77	1.16	0.02	0.00
11	5	-0.06	-0.06	-0.20	0.49	0.20	0.02	-5.3	-0.1	10.7	7.4	0.2	0.2	-4.58	-0.13	0.47	1.14	0.04	0.00
	10	-0.15	-0.07	-0.14	0.64	0.24	0.03	-7.1	-0.2	12.9	9.3	0.2	0.2	-4.55	-0.12	0.46	1.14	0.04	0.00
	15	-0.29	-0.08	-0.00	0.83	0.28	0.04	-8.9	-0.2	15.1	11.1	0.2	0.3	-4.52	-0.12	0.46	1.15	0.04	0.00
	20	-0.52	-0.09	0.28	1.09	0.31	0.04	-11.2	-0.3	17.4	13.2	0.2	0.4	-4.57	-0.12	0.46	1.15	0.04	0.00
12	5	-0.01	-0.04	0.27	0.17	0.12	0.03	-3.0	-0.1	9.6	3.7	0.2	0.1	-2.10	-0.23	0.34	1.14	0.06	-0.00
	10	-0.04	-0.05	0.21	0.22	0.17	0.04	-3.6	-0.2	10.3	4.2	0.2	0.2	-2.15	-0.23	0.33	1.14	0.06	-0.00
	15	-0.08	-0.06	0.23	0.27	0.21	0.04	-4.1	-0.2	10.8	4.6	0.2	0.2	-2.17	-0.23	0.32	1.15	0.06	-0.00
	20	-0.14	-0.07	0.28	0.34	0.24	0.05	-4.6	-0.2	11.4	5.0	0.3	0.2	-2.17	-0.24	0.31	1.15	0.06	-0.00
13	5	0.00	-0.04	-0.15	0.21	0.12	0.03	-3.2	-0.1	7.0	4.2	0.1	0.1	-3.94	-0.12	0.41	1.12	0.03	-0.00
	10	-0.03	-0.05	-0.13	0.26	0.15	0.03	-3.8	-0.1	7.8	4.9	0.1	0.1	-3.96	-0.11	0.41	1.12	0.03	0.00
	15	-0.08	-0.06	-0.10	0.33	0.18	0.04	-4.3	-0.1	8.5	5.4	0.0	0.1	-3.96	-0.11	0.41	1.13	0.03	0.00
	20	-0.13	-0.07	-0.04	0.39	0.20	0.05	-4.8	-0.1	9.2	6.0	0.0	0.1	-3.95	-0.11	0.40	1.13	0.03	0.00
14	5	0.02	-0.04	-0.17	0.21	0.12	0.03	-3.3	-0.1	7.1	4.5	0.1	0.1	-3.22	-0.12	0.37	1.12	0.03	-0.00
	10	-0.01	-0.05	-0.17	0.27	0.15	0.03	-4.0	-0.1	8.0	5.3	0.0	0.1	-3.23	-0.12	0.37	1.13	0.03	-0.00
	15	-0.05	-0.06	-0.14	0.32	0.18	0.04	-4.6	-0.1	8.8	5.9	0.0	0.1	-3.20	-0.12	0.36	1.13	0.03	0.00
	20	-0.10	-0.07	-0.08	0.39	0.20	0.05	-5.2	-0.1	9.4	6.5	-0.0	0.1	-3.17	-0.12	0.36	1.13	0.03	0.00
15	5	0.01	-0.04	-0.09	0.25	0.10	0.02	-2.5	-0.1	6.3	3.9	0.1	0.1	-2.78	-0.24	0.30	1.11	0.05	-0.00
	10	0.01	-0.05	-0.13	0.29	0.13	0.03	-3.0	-0.2	7.0	4.5	0.1	0.2	-2.75	-0.24	0.29	1.12	0.05	-0.00
	15	-0.01	-0.06	-0.14	0.33	0.16	0.03	-3.5	-0.2	7.3	4.8	0.1	0.2	-2.67	-0.25	0.28	1.13	0.05	-0.00
	20	-0.03	-0.07	-0.13	0.38	0.18	0.04	-3.9	-0.2	7.6	5.2	0.1	0.3	-2.63	-0.26	0.27	1.13	0.05	0.00
16	5	0.05	-0.04	0.98	0.10	0.08	0.03	-2.7	-0.1	12.5	3.3	0.2	0.1	-1.48	-0.34	0.37	1.15	0.05	-0.00
	10	0.04	-0.06	0.94	0.11	0.13	0.04	-3.3	-0.1	12.9	3.8	0.2	0.1	-1.43	-0.35	0.35	1.16	0.05	-0.00
	15	0.02	-0.07	1.00	0.15	0.17	0.05	-3.9	-0.1	13.5	4.2	0.2	0.1	-1.43	-0.36	0.34	1.16	0.05	-0.00
	20	-0.03	-0.08	1.03	0.19	0.21	0.06	-4.4	-0.1	13.9	4.5	0.2	0.1	-1.46	-0.37	0.33	1.16	0.05	-0.00
17	5	0.04	-0.03	0.36	0.07	0.10	0.02	-2.0	-0.1	11.1	2.5	0.2	0.1	-2.01	-0.46	0.24	1.15	0.06	-0.00
	10	0.05	-0.05	0.33	0.08	0.16	0.03	-2.5	-0.1	11.5	2.8	0.2	0.1	-1.87	-0.48	0.22	1.15	0.06	-0.00
	15	0.04	-0.06	0.27	0.10	0.21	0.04	-2.9	-0.1	11.7	3.1	0.2	0.1	-1.90	-0.50	0.20	1.16	0.06	-0.00
	20	0.01	-0.07	0.30	0.13	0.25	0.05	-3.3	-0.1	12.0	3.4	0.2	0.1	-1.93	-0.51	0.20	1.16	0.07	-0.00
18	5	-0.00	-0.03	0.23	0.12	0.09	0.02	-2.3	-0.0	8.7	3.0	0.1	0.0	-3.67	-0.10	0.41	1.13	0.04	-0.00
	10	-0.03	-0.04	0.24	0.15	0.13	0.03	-2.7	-0.0	9.4	3.3	0.1	0.0	-3.65	-0.10	0.39	1.13	0.04	-0.00
	15	-0.06	-0.05	0.22	0.18	0.16	0.04	-3.1	-0.1	9.8	3.6	0.0	0.1	-3.67	-0.10	0.39	1.14	0.04	-0.00
	20	-0.10	-0.05	0.24	0.22	0.19	0.04	-3.5	-0.1	10.2	3.9	0.0	0.1	-3.69	-0.10	0.38	1.14	0.04	-0.00

TABLE A(III)-29 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	0.01	-0.04	-0.02	0.15	0.13	0.03	-3.1	-0.1	8.6	3.9	0.1	0.1	-2.92	-0.14	0.35	1.13	0.04	-0.00
	10	-0.02	-0.06	-0.06	0.19	0.17	0.04	-3.6	-0.1	9.1	4.3	0.0	0.1	-2.95	-0.14	0.34	1.13	0.05	-0.00
	15	-0.06	-0.07	-0.07	0.23	0.21	0.05	-4.1	-0.1	9.5	4.8	0.0	0.1	-2.97	-0.14	0.34	1.14	0.05	-0.00
	20	-0.10	-0.08	-0.04	0.27	0.24	0.06	-4.6	-0.1	9.9	5.2	0.0	0.1	-2.96	-0.15	0.33	1.14	0.05	-0.00
20	5	0.04	-0.04	-0.14	0.19	0.13	0.03	-3.1	-0.1	8.6	4.2	0.0	0.1	-2.77	-0.19	0.28	1.13	0.05	-0.00
	10	0.02	-0.06	-0.19	0.23	0.18	0.04	-3.8	-0.1	9.1	4.9	0.0	0.1	-2.77	-0.18	0.28	1.13	0.05	-0.00
	15	-0.01	-0.07	-0.18	0.28	0.22	0.05	-4.4	-0.1	9.7	5.5	0.0	0.1	-2.73	-0.19	0.27	1.14	0.05	-0.00
	20	-0.07	-0.08	-0.13	0.35	0.25	0.05	-5.1	-0.1	10.3	6.1	0.0	0.1	-2.72	-0.19	0.26	1.14	0.05	-0.00
21	5	0.02	-0.04	-0.10	0.21	0.12	0.03	-2.8	-0.1	7.7	4.1	0.1	0.1	-2.82	-0.17	0.30	1.12	0.05	-0.00
	10	0.00	-0.05	-0.14	0.25	0.16	0.03	-3.4	-0.1	8.3	4.7	0.0	0.1	-2.84	-0.17	0.29	1.13	0.05	-0.00
	15	-0.03	-0.06	-0.14	0.30	0.19	0.04	-4.0	-0.1	8.8	5.2	0.0	0.2	-2.80	-0.17	0.28	1.13	0.05	-0.00
	20	-0.07	-0.07	-0.11	0.35	0.22	0.05	-4.5	-0.1	9.1	5.7	0.1	0.2	-2.77	-0.17	0.28	1.14	0.05	-0.00
25	5	0.04	-0.04	0.25	0.14	0.10	0.03	-2.2	-0.1	8.5	3.1	0.1	0.1	-2.53	-0.23	0.36	1.13	0.05	-0.00
	10	0.02	-0.05	0.24	0.18	0.13	0.03	-2.7	-0.1	8.7	3.5	0.2	0.1	-2.57	-0.23	0.36	1.14	0.05	-0.00
	15	-0.00	-0.06	0.23	0.21	0.17	0.04	-3.1	-0.1	9.0	3.9	0.2	0.1	-2.58	-0.23	0.36	1.14	0.05	-0.00
	20	-0.04	-0.07	0.27	0.25	0.20	0.05	-3.5	-0.1	9.3	4.1	0.2	0.1	-2.61	-0.23	0.36	1.14	0.05	-0.00
26	5	-0.05	-0.03	0.11	0.26	0.10	0.02	-2.6	-0.1	7.4	3.8	0.2	0.2	-4.25	-0.10	0.62	1.11	0.04	0.00
	10	-0.08	-0.05	0.13	0.32	0.14	0.02	-3.1	-0.2	7.7	4.3	0.3	0.3	-4.24	-0.11	0.61	1.11	0.04	0.00
	15	-0.11	-0.06	0.13	0.37	0.17	0.03	-3.5	-0.3	8.0	4.6	0.3	0.3	-4.28	-0.11	0.60	1.12	0.04	0.00
	20	-0.16	-0.07	0.18	0.43	0.19	0.04	-3.9	-0.4	8.3	4.8	0.4	0.4	-4.33	-0.11	0.61	1.12	0.04	0.00
27	5	-0.09	-0.03	0.14	0.49	0.09	-0.00	-3.2	-0.2	6.3	4.9	0.4	0.4	-5.03	-0.27	0.58	1.12	0.04	0.00
	10	-0.13	-0.05	0.21	0.60	0.11	0.00	-3.9	-0.4	7.0	5.5	0.5	0.6	-4.98	-0.28	0.57	1.12	0.04	0.00
	15	-0.18	-0.06	0.28	0.72	0.14	0.01	-4.4	-0.6	7.4	5.8	0.7	0.8	-4.74	-0.31	0.56	1.13	0.05	0.00
	20	-0.22	-0.08	0.33	0.82	0.16	0.02	-4.8	-0.9	7.5	5.9	1.0	1.1	-4.77	-0.31	0.56	1.14	0.05	0.00

TABLE A(III)-30. FALL PLOW SOYBEANS, FALL FERTILIZATION (A SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.02	-0.06	4.30	0.26	-0.21	0.05	-5.5	-0.1	39.3	7.4	0.6	0.1	0.14	-0.30	0.05	1.17	-0.00	-0.00
	10	-0.19	-0.08	6.24	0.46	-0.30	0.07	-7.7	-0.1	48.1	9.4	0.7	0.1	0.18	-0.31	0.05	1.17	-0.00	-0.00
	15	-0.48	-0.09	8.45	0.75	-0.39	0.08	-11.0	-0.2	57.0	12.1	0.9	0.2	0.15	-0.31	0.05	1.18	-0.00	-0.00
	20	-0.93	-0.10	10.61	1.20	-0.45	0.09	-16.3	-0.3	68.8	16.5	1.2	0.3	0.12	-0.30	0.05	1.18	0.00	-0.00
2	5	0.04	-0.05	4.79	0.05	-0.20	0.05	-3.7	-0.1	31.4	4.7	0.8	0.1	0.31	-0.31	0.04	1.18	0.00	-0.00
	10	-0.03	-0.06	5.86	0.13	-0.23	0.06	-5.2	-0.1	36.6	5.9	1.0	0.1	0.33	-0.31	0.04	1.18	0.00	-0.00
	15	-0.16	-0.07	6.95	0.27	-0.26	0.07	-7.0	-0.2	41.5	7.2	1.1	0.2	0.38	-0.32	0.04	1.18	0.00	-0.00
	20	-0.35	-0.08	7.87	0.45	-0.27	0.07	-8.9	-0.3	45.6	8.6	1.3	0.2	0.37	-0.31	0.04	1.18	0.00	-0.00
3	5	0.02	-0.02	2.46	0.02	-0.09	0.02	-1.2	-0.0	17.2	1.8	0.5	0.0	0.11	-0.34	0.04	1.17	0.00	-0.00
	10	0.03	-0.03	2.92	0.02	-0.12	0.03	-1.4	-0.0	18.2	2.0	0.6	0.1	0.18	-0.35	0.04	1.17	0.00	-0.00
	15	0.03	-0.03	3.28	0.03	-0.13	0.03	-1.6	-0.1	18.6	2.1	0.7	0.1	0.19	-0.36	0.04	1.17	0.00	-0.00
	20	0.02	-0.04	3.64	0.04	-0.14	0.04	-1.9	-0.1	18.7	2.2	0.7	0.1	0.23	-0.37	0.04	1.17	0.00	-0.00
4	5	0.04	-0.04	3.23	0.12	-0.17	0.03	-2.7	-0.1	21.9	3.8	0.8	0.1	-0.30	-0.37	0.07	1.17	-0.00	-0.00
	10	0.02	-0.05	4.24	0.18	-0.23	0.04	-3.3	-0.1	25.1	4.5	1.1	0.2	-0.19	-0.39	0.07	1.17	-0.00	-0.00
	15	-0.03	-0.06	5.26	0.25	-0.30	0.05	-4.0	-0.2	27.6	5.1	1.4	0.2	-0.15	-0.40	0.08	1.17	-0.00	-0.00
	20	-0.10	-0.07	6.30	0.35	-0.35	0.06	-4.8	-0.3	29.3	5.8	1.7	0.3	-0.11	-0.41	0.08	1.17	-0.00	-0.00
5	5	0.09	-0.03	2.88	0.04	-0.12	0.03	-1.9	-0.1	18.5	2.9	0.6	0.1	-0.39	-0.50	0.11	1.17	-0.00	-0.00
	10	0.09	-0.05	3.47	0.06	-0.15	0.04	-2.3	-0.1	20.6	3.3	0.8	0.1	-0.33	-0.51	0.11	1.17	-0.00	-0.00
	15	0.08	-0.05	4.08	0.09	-0.19	0.05	-2.7	-0.1	22.0	3.6	1.0	0.1	-0.28	-0.53	0.12	1.17	-0.00	-0.00
	20	0.06	-0.06	4.63	0.12	-0.22	0.06	-3.2	-0.1	23.2	4.0	1.2	0.2	-0.31	-0.54	0.12	1.17	-0.00	-0.00
6	5	-0.19	-0.05	5.32	0.44	-0.43	0.03	-7.0	-0.2	39.5	9.1	1.2	0.3	-0.49	-0.39	0.05	1.17	-0.00	-0.00
	10	-0.45	-0.06	8.29	0.82	-0.65	0.03	-10.8	-0.4	51.1	12.7	1.8	0.4	0.11	-0.45	0.06	1.17	-0.00	-0.00
	15	-0.92	-0.06	11.37	1.36	-0.85	0.02	-15.9	-0.6	62.4	17.2	2.3	0.6	0.20	-0.46	0.07	1.18	-0.00	-0.00
	20	-1.65	-0.04	14.39	2.11	-1.01	-0.00	-22.9	-1.1	74.7	23.0	3.2	1.0	0.36	-0.48	0.07	1.18	-0.00	-0.00
7	5	-0.12	-0.04	5.03	0.41	-0.38	0.03	-4.8	-0.2	24.0	6.6	1.0	0.3	-1.43	-0.31	0.13	1.16	-0.01	-0.00
	10	-0.32	-0.05	7.07	0.70	-0.53	0.02	-6.7	-0.3	29.6	8.5	1.6	0.4	-1.26	-0.33	0.14	1.17	-0.01	-0.00
	15	-0.66	-0.05	9.56	1.13	-0.72	0.01	-8.9	-0.5	35.0	10.7	2.1	0.6	-1.20	-0.34	0.15	1.17	-0.01	-0.00
	20	-1.10	-0.04	11.65	1.62	-0.85	0.00	-11.8	-0.9	40.1	13.2	2.7	0.9	-1.20	-0.35	0.14	1.17	-0.01	-0.00
8	5	0.02	-0.03	2.77	0.12	-0.16	0.03	-2.1	-0.1	14.9	3.2	0.5	0.1	-1.70	-0.34	0.17	1.15	-0.01	-0.00
	10	-0.01	-0.04	3.32	0.17	-0.20	0.03	-2.5	-0.1	16.5	3.6	0.7	0.1	-1.68	-0.34	0.18	1.15	-0.01	-0.00
	15	-0.04	-0.05	3.81	0.22	-0.23	0.04	-3.0	-0.1	17.7	4.0	0.9	0.2	-1.65	-0.35	0.18	1.16	-0.01	-0.00
	20	-0.09	-0.06	4.35	0.29	-0.26	0.05	-3.4	-0.1	18.6	4.3	1.0	0.2	-1.68	-0.35	0.19	1.16	-0.01	-0.00
9	5	-0.43	-0.04	2.98	0.84	-0.22	0.01	-9.9	-0.5	36.0	12.7	1.6	0.6	-8.14	0.08	0.09	1.15	-0.01	0.00
	10	-0.83	-0.05	3.73	1.28	-0.20	0.01	-14.7	-0.9	45.8	18.8	2.3	1.0	-8.87	0.16	0.09	1.15	-0.01	0.00
	15	-1.53	-0.05	5.04	1.98	-0.19	0.01	-24.0	-1.8	51.6	24.6	3.5	1.8	-9.42	0.20	0.10	1.16	-0.01	0.00
	20	-2.56	-0.07	6.74	2.89	-0.15	0.03	-31.3	-3.0	56.4	30.3	4.9	2.9	-9.47	0.21	0.10	1.16	-0.01	0.00

TABLE A(III)-36 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.04	-0.02	2.60	0.27	-0.04	0.02	-3.9	-0.1	15.1	5.3	0.5	0.2	-2.36	-0.09	0.29	1.15	-0.01	-0.00
	10	-0.10	-0.03	2.87	0.35	-0.04	0.03	-4.9	-0.2	17.1	6.3	0.6	0.2	-2.37	-0.09	0.29	1.15	-0.01	0.00
	15	-0.17	-0.04	3.10	0.43	-0.03	0.04	-5.9	-0.2	18.7	7.1	0.8	0.2	-2.39	-0.09	0.29	1.16	-0.01	0.00
	20	-0.25	-0.05	3.34	0.51	-0.03	0.05	-6.9	-0.3	20.0	8.0	0.9	0.3	-2.39	-0.09	0.29	1.16	-0.01	0.00
20	5	-0.01	-0.02	2.64	0.33	-0.07	0.02	-4.0	-0.1	14.3	5.8	0.5	0.2	-2.44	-0.11	0.27	1.15	-0.01	-0.00
	10	-0.07	-0.03	2.99	0.42	-0.07	0.03	-5.3	-0.2	17.0	7.1	0.8	0.3	-2.45	-0.11	0.27	1.15	-0.01	-0.00
	15	-0.15	-0.05	3.32	0.52	-0.07	0.04	-6.5	-0.3	19.1	8.3	0.9	0.3	-2.44	-0.11	0.27	1.16	-0.01	0.00
	20	-0.25	-0.06	3.65	0.65	-0.06	0.05	-8.1	-0.4	21.2	9.7	1.1	0.4	-2.45	-0.11	0.27	1.16	-0.01	0.00
21	5	-0.01	-0.02	2.36	0.36	-0.06	0.02	-3.7	-0.2	12.1	5.5	0.6	0.2	-2.47	-0.11	0.26	1.14	-0.01	-0.00
	10	-0.06	-0.03	2.68	0.44	-0.07	0.03	-4.7	-0.3	14.0	6.5	0.8	0.4	-2.48	-0.11	0.26	1.15	-0.01	0.00
	15	-0.13	-0.05	2.95	0.53	-0.07	0.04	-5.6	-0.4	15.3	7.5	1.1	0.5	-2.47	-0.11	0.26	1.15	-0.01	0.00
	20	-0.22	-0.06	3.24	0.65	-0.06	0.05	-6.7	-0.6	16.0	8.4	1.4	0.6	-2.45	-0.11	0.25	1.16	-0.01	0.00
25	5	0.03	-0.02	3.01	0.25	-0.09	0.02	-2.5	-0.1	13.6	4.0	0.6	0.2	-2.02	-0.15	0.24	1.15	-0.01	-0.00
	10	0.00	-0.03	3.38	0.30	-0.10	0.02	-3.2	-0.2	15.0	4.6	0.9	0.2	-2.04	-0.15	0.24	1.15	-0.01	-0.00
	15	-0.04	-0.04	3.72	0.36	-0.11	0.03	-3.8	-0.2	15.8	5.2	1.1	0.3	-2.05	-0.15	0.24	1.16	-0.01	0.00
	20	-0.09	-0.05	4.05	0.43	-0.11	0.04	-4.5	-0.3	16.1	5.6	1.4	0.4	-2.07	-0.15	0.24	1.16	-0.01	0.00
26	5	-0.03	-0.03	2.99	0.44	-0.15	0.01	-2.8	-0.2	9.8	4.4	0.8	0.3	-2.81	-0.15	0.12	1.14	-0.01	0.00
	10	-0.08	-0.04	3.33	0.52	-0.16	0.02	-3.4	-0.4	10.3	4.9	1.2	0.5	-2.81	-0.15	0.12	1.14	-0.01	0.00
	15	-0.13	-0.05	3.67	0.62	-0.17	0.03	-3.9	-0.6	10.0	5.1	1.5	0.7	-2.81	-0.16	0.12	1.15	-0.01	0.00
	20	-0.20	-0.07	3.97	0.72	-0.17	0.04	-4.3	-0.8	9.4	5.3	1.8	0.9	-2.83	-0.16	0.12	1.15	-0.01	0.00
27	5	-0.06	-0.03	3.51	0.87	-0.21	-0.02	-3.3	-0.3	9.6	5.3	1.1	0.5	-3.50	-0.31	0.14	1.14	-0.01	0.00
	10	-0.12	-0.05	4.37	1.09	-0.25	-0.01	-4.0	-0.7	9.5	5.7	1.6	0.9	-3.40	-0.33	0.14	1.14	-0.01	0.00
	15	-0.20	-0.07	5.20	1.33	-0.28	0.00	-4.3	-1.2	8.2	5.6	2.1	1.4	-3.24	-0.35	0.13	1.15	-0.01	0.00
	20	-0.29	-0.11	5.75	1.52	-0.28	0.02	-4.1	-2.0	6.4	5.8	2.8	2.1	-3.19	-0.36	0.13	1.15	-0.01	0.00

TABLE A(III)-30 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.26	-0.04	3.10	0.70	-0.22	0.01	-6.7	-0.2	28.1	9.9	0.9	0.3	-7.43	0.09	0.20	1.14	-0.02	0.00
	10	-0.52	-0.04	4.11	1.06	-0.27	0.01	-10.1	-0.4	31.2	13.4	1.2	0.5	-7.77	0.12	0.20	1.15	-0.02	0.00
	15	-0.82	-0.05	4.25	1.39	-0.22	0.02	-14.2	-0.7	35.5	17.1	1.6	0.8	-7.97	0.15	0.18	1.15	-0.01	0.00
	20	-1.27	-0.07	4.67	1.82	-0.17	0.03	-19.7	-1.2	40.8	21.9	2.2	1.2	-8.12	0.16	0.16	1.16	-0.01	0.00
11	5	-0.07	-0.05	2.70	0.49	-0.18	0.02	-4.4	-0.1	16.5	7.2	0.5	0.2	-4.58	-0.13	0.32	1.14	-0.02	0.00
	10	-0.15	-0.06	3.12	0.64	-0.20	0.03	-6.0	-0.2	19.9	9.1	0.6	0.2	-4.55	-0.12	0.32	1.14	-0.02	0.00
	15	-0.27	-0.07	3.62	0.83	-0.22	0.03	-7.7	-0.2	22.6	10.9	0.7	0.3	-4.52	-0.12	0.32	1.15	-0.02	0.00
	20	-0.46	-0.08	4.19	1.08	-0.24	0.04	-9.9	-0.3	25.2	12.9	0.8	0.3	-4.57	-0.12	0.33	1.15	-0.02	0.00
12	5	-0.01	-0.03	2.02	0.17	-0.13	0.03	-2.5	-0.1	12.4	3.6	0.5	0.1	-2.10	-0.23	0.19	1.14	-0.01	-0.00
	10	-0.04	-0.04	2.34	0.22	-0.15	0.03	-3.0	-0.1	13.9	4.0	0.6	0.2	-2.15	-0.23	0.19	1.14	-0.01	-0.00
	15	-0.08	-0.05	2.69	0.27	-0.17	0.04	-3.4	-0.1	15.1	4.5	0.8	0.2	-2.17	-0.23	0.19	1.15	-0.01	-0.00
	20	-0.13	-0.06	3.08	0.34	-0.19	0.05	-3.8	-0.2	16.1	4.9	0.9	0.2	-2.17	-0.24	0.20	1.15	-0.01	-0.00
13	5	-0.00	-0.03	1.65	0.21	-0.08	0.02	-2.6	-0.0	10.5	4.1	0.3	0.1	-3.94	-0.12	0.34	1.12	-0.02	-0.00
	10	-0.04	-0.04	1.82	0.27	-0.09	0.03	-3.1	-0.1	11.9	4.7	0.3	0.1	-3.96	-0.11	0.34	1.12	-0.02	0.00
	15	-0.08	-0.05	1.99	0.33	-0.09	0.04	-3.5	-0.1	13.1	5.3	0.3	0.1	-3.96	-0.11	0.35	1.13	-0.02	0.00
	20	-0.12	-0.05	2.15	0.39	-0.10	0.04	-4.0	-0.1	14.2	5.8	0.3	0.1	-3.95	-0.11	0.35	1.13	-0.02	0.00
14	5	0.01	-0.03	1.62	0.21	-0.07	0.03	-2.7	-0.0	10.8	4.4	0.2	0.1	-3.22	-0.12	0.38	1.12	-0.02	-0.00
	10	-0.02	-0.04	1.81	0.27	-0.08	0.03	-3.3	-0.1	12.4	5.1	0.3	0.1	-3.23	-0.12	0.38	1.13	-0.02	-0.00
	15	-0.05	-0.05	1.97	0.32	-0.08	0.04	-3.8	-0.1	13.6	5.8	0.3	0.1	-3.20	-0.12	0.39	1.13	-0.02	0.00
	20	-0.10	-0.06	2.14	0.39	-0.09	0.05	-4.3	-0.1	14.7	6.4	0.3	0.1	-3.17	-0.12	0.39	1.13	-0.02	0.00
15	5	0.01	-0.03	1.32	0.26	-0.08	0.02	-2.2	-0.1	8.1	3.9	0.3	0.1	-2.78	-0.24	0.24	1.11	-0.01	-0.00
	10	-0.00	-0.04	1.52	0.29	-0.09	0.03	-2.6	-0.1	9.0	4.4	0.5	0.2	-2.75	-0.24	0.24	1.12	-0.01	-0.00
	15	-0.02	-0.05	1.65	0.34	-0.10	0.03	-3.0	-0.2	9.4	4.7	0.6	0.2	-2.67	-0.25	0.24	1.13	-0.02	-0.00
	20	-0.03	-0.06	1.81	0.38	-0.10	0.04	-3.4	-0.2	9.8	5.1	0.7	0.3	-2.63	-0.26	0.24	1.13	-0.01	0.00
16	5	0.04	-0.03	2.72	0.10	-0.09	0.03	-1.9	-0.0	17.2	3.2	0.4	0.1	-1.40	-0.34	0.22	1.15	-0.01	-0.00
	10	0.03	-0.04	3.15	0.12	-0.11	0.04	-2.3	-0.0	19.1	3.6	0.4	0.1	-1.43	-0.35	0.22	1.16	-0.01	-0.00
	15	0.01	-0.05	3.52	0.15	-0.13	0.05	-2.8	-0.1	20.7	4.0	0.5	0.1	-1.43	-0.36	0.23	1.16	-0.01	-0.00
	20	-0.02	-0.06	3.92	0.19	-0.14	0.06	-3.3	-0.1	21.6	4.3	0.6	0.1	-1.46	-0.37	0.23	1.16	-0.01	-0.00
17	5	0.04	-0.03	2.43	0.07	-0.08	0.02	-1.4	-0.0	14.9	2.4	0.4	0.1	-2.01	-0.46	0.23	1.15	-0.01	-0.00
	10	0.04	-0.04	2.83	0.08	-0.10	0.03	-1.7	-0.0	16.4	2.7	0.5	0.1	-1.87	-0.48	0.23	1.15	-0.01	-0.00
	15	0.03	-0.05	3.22	0.10	-0.12	0.04	-1.9	-0.0	17.6	2.9	0.5	0.1	-1.90	-0.50	0.24	1.16	-0.01	-0.00
	20	0.01	-0.05	3.60	0.13	-0.14	0.05	-2.3	-0.1	18.6	3.2	0.6	0.1	-1.93	-0.51	0.24	1.16	-0.01	-0.00
18	5	-0.01	-0.03	2.14	0.12	-0.10	0.02	-1.8	-0.0	11.6	2.9	0.2	0.0	-3.67	-0.10	0.35	1.13	-0.02	-0.00
	10	-0.03	-0.03	2.33	0.15	-0.11	0.03	-2.1	-0.0	12.7	3.2	0.2	0.0	-3.65	-0.10	0.35	1.13	-0.02	-0.00
	15	-0.06	-0.04	2.51	0.18	-0.12	0.04	-2.5	-0.0	13.6	3.5	0.3	0.0	-3.67	-0.10	0.36	1.14	-0.02	-0.00
	20	-0.09	-0.04	2.69	0.22	-0.12	0.04	-2.8	-0.0	14.3	3.8	0.3	0.1	-3.69	-0.10	0.36	1.14	-0.02	-0.00

TABLE A(III)-30 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	0.00	-0.04	1.97	0.15	-0.07	0.03	-2.6	-0.0	11.7	3.8	0.2	0.1	-2.92	-0.14	0.37	1.13	-0.01	-0.00
	10	-0.02	-0.05	2.17	0.19	-0.07	0.04	-3.0	-0.1	13.0	4.2	0.3	0.1	-2.95	-0.14	0.38	1.13	-0.02	-0.00
	15	-0.06	-0.06	2.33	0.22	-0.08	0.05	-3.4	-0.1	14.1	4.6	0.3	0.1	-2.97	-0.14	0.38	1.14	-0.02	-0.00
	20	-0.09	-0.06	2.47	0.27	-0.08	0.06	-3.9	-0.1	14.9	5.0	0.3	0.1	-2.96	-0.15	0.38	1.14	-0.02	-0.00
20	5	0.03	-0.04	1.79	0.19	-0.09	0.03	-2.6	-0.0	11.4	4.1	0.3	0.1	-2.77	-0.19	0.33	1.13	-0.02	-0.00
	10	0.01	-0.05	2.03	0.23	-0.10	0.04	-3.1	-0.1	12.9	4.8	0.3	0.1	-2.77	-0.18	0.33	1.13	-0.02	-0.00
	15	-0.02	-0.06	2.24	0.28	-0.11	0.04	-3.7	-0.1	14.2	5.3	0.4	0.1	-2.73	-0.19	0.33	1.14	-0.02	-0.00
	20	-0.06	-0.06	2.44	0.34	-0.12	0.05	-4.3	-0.1	15.4	5.9	0.4	0.1	-2.72	-0.19	0.33	1.14	-0.02	-0.00
21	5	0.02	-0.03	1.51	0.21	-0.07	0.02	-2.4	-0.1	9.7	4.0	0.3	0.1	-2.82	-0.17	0.29	1.12	-0.02	-0.00
	10	-0.00	-0.04	1.71	0.25	-0.09	0.03	-2.9	-0.1	11.0	4.6	0.4	0.1	-2.84	-0.17	0.30	1.13	-0.02	-0.00
	15	-0.03	-0.05	1.85	0.30	-0.09	0.04	-3.4	-0.1	12.1	5.1	0.4	0.1	-2.80	-0.17	0.30	1.13	-0.02	-0.00
	20	-0.07	-0.06	2.02	0.35	-0.10	0.05	-3.9	-0.1	13.0	5.6	0.5	0.2	-2.77	-0.17	0.29	1.14	-0.02	-0.00
25	5	0.03	-0.03	2.08	0.14	-0.12	0.02	-1.7	-0.0	11.4	3.1	0.3	0.1	-2.53	-0.23	0.27	1.13	-0.01	-0.00
	10	0.02	-0.04	2.32	0.18	-0.13	0.03	-2.0	-0.1	12.5	3.4	0.4	0.1	-2.57	-0.23	0.27	1.14	-0.01	-0.00
	15	-0.00	-0.05	2.55	0.21	-0.14	0.04	-2.4	-0.1	13.3	3.7	0.5	0.1	-2.58	-0.23	0.27	1.14	-0.02	-0.00
	20	-0.03	-0.05	2.78	0.25	-0.16	0.05	-2.7	-0.1	14.0	4.0	0.6	0.1	-2.61	-0.23	0.27	1.14	-0.02	-0.00
26	5	-0.05	-0.03	1.54	0.26	-0.11	0.02	-2.3	-0.1	9.1	3.7	0.5	0.2	-4.25	-0.10	0.12	1.11	-0.01	0.00
	10	-0.08	-0.04	1.71	0.32	-0.12	0.02	-2.7	-0.2	10.0	4.2	0.7	0.3	-4.24	-0.11	0.12	1.11	-0.01	0.00
	15	-0.11	-0.05	1.86	0.37	-0.13	0.03	-3.0	-0.2	10.3	4.5	0.9	0.3	-4.28	-0.11	0.12	1.12	-0.01	0.00
	20	-0.15	-0.05	1.99	0.42	-0.13	0.04	-3.4	-0.3	10.4	4.7	1.0	0.4	-4.33	-0.11	0.12	1.12	-0.01	0.00
27	5	-0.08	-0.03	1.79	0.49	-0.14	-0.00	-2.7	-0.2	9.4	4.8	0.8	0.4	-5.03	-0.27	0.11	1.12	-0.01	0.00
	10	-0.11	-0.04	2.17	0.60	-0.16	0.00	-3.3	-0.3	10.0	5.4	1.1	0.6	-4.98	-0.28	0.11	1.12	-0.01	0.00
	15	-0.15	-0.05	2.57	0.71	-0.19	0.01	-3.8	-0.5	10.0	5.7	1.4	0.8	-4.74	-0.31	0.10	1.13	-0.01	0.00
	20	-0.20	-0.07	2.80	0.81	-0.19	0.02	-4.2	-0.8	9.5	5.8	1.8	1.1	-4.77	-0.31	0.09	1.14	-0.01	0.00

TABLE A(III)-31. FALL PLOW SOYBEANS (B SOILS ONLY)

REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′	REGION	AW	A	B	A′	B′
1	5	0.69	5.67	-0.63	43.11	10	5	1.45	5.33	-1.38	49.39	19	5	1.13	15.47	-1.10	52.65
	10	0.62	5.62	-0.51	31.44		10	1.41	5.20	-1.14	35.10		10	1.13	15.30	-1.04	45.62
	15	0.57	5.38	-0.43	22.98		15	1.33	4.89	-1.01	26.45		15	1.10	15.12	-0.97	40.72
	20	0.51	5.26	-0.38	15.57		20	1.28	4.64	-0.90	19.30		20	1.08	14.88	-0.95	36.82
2	5	1.09	8.60	-1.05	45.40	11	5	1.31	9.73	-1.26	53.22	20	5	1.16	16.08	-1.13	52.64
	10	1.02	8.63	-0.93	35.16		10	1.25	9.61	-1.04	40.75		10	1.17	15.88	-1.06	44.14
	15	0.96	8.58	-0.82	27.69		15	1.23	9.28	-0.91	32.93		15	1.16	15.68	-0.98	38.41
	20	0.89	8.64	-0.75	22.12		20	1.20	8.96	-0.82	26.71		20	1.12	15.49	-0.88	33.63
3	5	1.50	11.83	-1.49	56.25	12	5	1.70	9.15	-1.67	57.96	21	5	1.37	16.77	-1.35	53.07
	10	1.54	11.54	-1.53	50.78		10	1.76	8.86	-1.68	49.70		10	1.41	16.48	-1.32	44.93
	15	1.54	11.43	-1.54	47.61		15	1.79	8.64	-1.64	44.05		15	1.40	16.20	-1.26	39.40
	20	1.53	11.24	-1.53	45.01		20	1.79	8.34	-1.58	39.49		20	1.38	15.98	-1.22	35.16
4	5	1.60	6.36	-1.57	53.01	13	5	1.23	18.87	-1.19	52.85	25	5	1.52	12.39	-1.50	58.78
	10	1.63	6.03	-1.53	43.64		10	1.22	18.80	-1.08	44.26		10	1.53	12.27	-1.48	51.38
	15	1.60	5.86	-1.44	37.03		15	1.20	18.62	-0.95	38.46		15	1.55	12.03	-1.50	46.40
	20	1.56	5.67	-1.44	32.04		20	1.18	18.38	-0.85	33.88		20	1.55	11.80	-1.49	42.53
5	5	1.54	8.71	-1.52	53.88	14	5	1.06	19.66	-1.02	50.36	26	5	2.23	7.18	-2.21	60.52
	10	1.57	8.54	-1.49	46.17		10	1.07	19.42	-0.90	41.62		10	2.30	6.76	-2.25	52.38
	15	1.56	8.32	-1.49	41.06		15	1.06	19.17	-0.80	35.93		15	2.35	6.33	-2.30	47.89
	20	1.56	8.13	-1.48	36.85		20	1.01	18.92	-0.71	31.41		20	2.36	6.12	-2.32	44.42
6	5	1.12	1.98	-1.03	42.14	15	5	1.78	15.21	-1.76	54.15	27	5	2.58	3.60	-2.56	58.72
	10	1.06	1.80	-0.81	28.19		10	1.82	14.84	-1.75	46.46		10	2.66	3.03	-2.61	50.11
	15	0.98	1.79	-0.65	19.73		15	1.84	14.50	-1.76	41.91		15	2.74	2.42	-2.63	44.81
	20	0.91	1.78	-0.58	13.43		20	1.84	14.22	-1.77	38.46		20	2.79	1.91	-2.66	40.83
7	5	1.60	1.89	-1.53	49.97	16	5	1.12	11.95	-1.09	53.91						
	10	1.64	1.55	-1.41	36.88		10	1.10	11.76	-1.02	46.60						
	15	1.61	1.28	-1.22	28.23		15	1.08	11.64	-0.97	41.28						
	20	1.57	1.15	-1.07	21.42		20	1.07	11.44	-0.98	37.43						
8	5	1.62	8.53	-1.58	55.76	17	5	1.34	10.93	-1.32	56.18						
	10	1.68	8.22	-1.59	47.86		10	1.36	10.71	-1.30	49.24						
	15	1.70	7.97	-1.56	42.52		15	1.34	10.53	-1.28	44.40						
	20	1.70	7.67	-1.56	38.53		20	1.34	10.37	-1.27	40.19						
9	5	1.49	1.04	-1.37	42.94	18	5	0.95	17.77	-0.94	54.31						
	10	1.39	0.85	-1.03	27.52		10	0.94	17.63	-0.90	47.84						
	15	1.33	0.71	-0.95	19.30		15	0.92	17.46	-0.86	43.20						
	20	1.26	0.64	-0.87	13.26		20	0.90	17.21	-0.86	39.36						

TABLE A(III)-32. FALL PLOW SOYBEANS, SPRING FERTILIZATION (B SOILS ONLY)

REGION			DISSOLVED N IN RUNOFF					DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.11	-0.05	2.70	0.40	0.08	0.03	-7.9	-0.1	31.8	8.4	0.3	0.1	-0.04	-0.19	0.34	1.17	0.04	-0.00
	10	-0.47	-0.06	3.39	0.73	0.15	0.04	-11.3	-0.2	37.3	11.1	0.4	0.2	-0.04	-0.19	0.33	1.17	0.04	-0.00
	15	-0.98	-0.08	4.29	1.15	0.22	0.05	-15.9	-0.3	45.3	14.7	0.6	0.3	-0.06	-0.19	0.32	1.18	0.04	-0.00
	20	-1.73	-0.08	5.90	1.76	0.26	0.06	-23.4	-0.6	60.0	20.6	1.2	0.5	-0.10	-0.18	0.32	1.18	0.04	-0.00
2	5	-0.01	-0.05	1.09	0.12	0.13	0.04	-5.6	-0.2	27.1	5.5	0.5	0.1	0.04	-0.22	0.13	1.18	0.05	-0.00
	10	-0.16	-0.06	1.40	0.26	0.20	0.05	-7.8	-0.3	31.3	7.1	0.6	0.2	0.04	-0.21	0.12	1.18	0.05	-0.00
	15	-0.40	-0.08	1.90	0.45	0.26	0.06	-10.5	-0.4	35.4	8.9	0.8	0.3	0.06	-0.21	0.11	1.18	0.05	-0.00
	20	-0.72	-0.09	2.68	0.69	0.30	0.06	-13.3	-0.5	40.3	10.8	1.2	0.4	0.04	-0.21	0.11	1.18	0.05	-0.00
3	5	0.02	-0.02	0.80	0.05	0.07	0.02	-2.2	-0.1	14.5	2.1	0.4	0.1	-0.05	-0.25	0.13	1.17	0.05	-0.00
	10	0.02	-0.03	0.81	0.06	0.11	0.02	-2.6	-0.1	14.9	2.4	0.4	0.1	-0.01	-0.26	0.12	1.17	0.05	-0.00
	15	0.01	-0.04	0.84	0.08	0.15	0.03	-2.9	-0.1	15.0	2.5	0.5	0.1	-0.00	-0.27	0.11	1.17	0.05	-0.00
	20	-0.02	-0.05	0.88	0.09	0.19	0.03	-3.2	-0.1	15.2	2.7	0.5	0.1	0.02	-0.27	0.10	1.17	0.05	-0.00
4	5	0.05	-0.04	1.27	0.16	0.09	0.03	-4.0	-0.2	17.7	4.3	0.5	0.2	-0.17	-0.30	0.24	1.17	0.06	-0.00
	10	-0.02	-0.06	1.31	0.26	0.15	0.04	-5.0	-0.3	19.6	5.1	0.7	0.2	-0.12	-0.31	0.22	1.17	0.06	-0.00
	15	-0.13	-0.07	1.49	0.37	0.20	0.04	-6.1	-0.3	21.4	6.0	0.9	0.3	-0.10	-0.32	0.20	1.17	0.06	-0.00
	20	-0.28	-0.08	1.80	0.52	0.25	0.05	-7.2	-0.5	23.0	6.7	1.2	0.5	-0.08	-0.32	0.19	1.17	0.06	-0.00
5	5	0.09	-0.03	0.64	0.08	0.09	0.02	-3.0	-0.1	15.1	3.3	0.4	0.1	-0.49	-0.39	0.16	1.17	0.06	-0.00
	10	0.07	-0.05	0.67	0.12	0.15	0.03	-3.7	-0.2	16.1	3.9	0.5	0.2	-0.46	-0.39	0.15	1.17	0.06	-0.00
	15	0.03	-0.06	0.71	0.17	0.19	0.04	-4.4	-0.2	16.9	4.3	0.6	0.2	-0.44	-0.41	0.14	1.17	0.06	-0.00
	20	-0.02	-0.08	0.84	0.22	0.23	0.05	-5.1	-0.3	17.6	4.7	0.8	0.3	-0.45	-0.41	0.13	1.17	0.06	-0.00
6	5	-0.20	-0.05	1.56	0.58	0.19	0.02	-9.4	-0.3	30.0	10.0	0.6	0.3	-0.02	-0.35	0.11	1.18	0.07	-0.00
	10	-0.70	-0.06	2.18	1.11	0.26	0.02	-14.3	-0.6	38.5	14.3	1.0	0.5	0.21	-0.37	0.05	1.18	0.08	-0.00
	15	-1.50	-0.05	3.59	1.86	0.28	0.00	-20.8	-0.9	50.2	19.6	1.7	0.8	0.25	-0.37	0.03	1.18	0.08	-0.00
	20	-2.64	-0.03	5.85	2.86	0.27	-0.02	-29.3	-1.7	66.2	26.5	3.1	1.5	0.28	-0.37	0.03	1.18	0.08	-0.00
7	5	-0.10	-0.05	1.12	0.51	0.14	0.02	-6.2	-0.3	19.2	7.1	0.5	0.3	-0.77	-0.31	0.22	1.17	0.07	-0.00
	10	-0.40	-0.06	1.34	0.88	0.20	0.02	-8.7	-0.5	23.1	9.4	0.9	0.6	-0.69	-0.33	0.19	1.17	0.07	-0.00
	15	-0.89	-0.06	1.97	1.39	0.24	0.01	-11.5	-0.8	27.3	11.8	1.4	0.8	-0.65	-0.33	0.17	1.17	0.08	-0.00
	20	-1.49	-0.06	2.93	1.98	0.27	0.01	-14.9	-1.4	32.5	14.7	2.2	1.3	-0.65	-0.34	0.16	1.17	0.08	-0.00
8	5	0.03	-0.03	0.52	0.15	0.09	0.02	-3.1	-0.1	12.3	3.6	0.3	0.1	-1.20	-0.29	0.22	1.16	0.05	-0.00
	10	-0.01	-0.05	0.53	0.21	0.14	0.03	-3.8	-0.2	13.3	4.1	0.4	0.2	-1.19	-0.29	0.21	1.16	0.06	-0.00
	15	-0.06	-0.06	0.58	0.28	0.18	0.04	-4.4	-0.2	14.1	4.6	0.5	0.2	-1.17	-0.30	0.20	1.16	0.06	-0.00
	20	-0.13	-0.07	0.66	0.36	0.21	0.04	-5.0	-0.3	14.8	5.0	0.6	0.3	-1.17	-0.31	0.19	1.16	0.06	-0.00
9	5	-0.50	-0.05	0.08	1.18	0.28	-0.01	-12.4	-0.6	26.1	13.7	1.0	0.7	-6.61	-0.05	0.62	1.16	0.03	0.00
	10	-1.16	-0.05	1.08	1.89	0.30	-0.02	-20.1	-1.2	37.2	20.4	1.8	1.2	-6.94	-0.01	0.65	1.16	0.03	0.00
	15	-2.32	-0.04	2.83	2.99	0.30	-0.04	-27.7	-2.4	47.5	26.6	3.6	2.3	-7.26	0.01	0.67	1.17	0.03	0.00
	20	-3.98	-0.04	5.31	4.46	0.31	-0.04	-33.8	-3.6	55.8	31.2	5.4	3.5	-7.51	0.02	0.70	1.17	0.03	0.00

TABLE A(III)-32 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.30	-0.04	-0.05	0.88	0.20	0.00	-8.9	-0.4	18.0	11.0	0.5	0.4	-6.40	-0.00	0.59	1.15	0.03	0.00
	10	-0.66	-0.05	0.33	1.35	0.25	0.00	-13.1	-0.6	23.7	15.0	0.8	0.7	-6.54	0.02	0.60	1.16	0.03	0.00
	15	-1.18	-0.06	1.04	1.88	0.28	0.01	-18.0	-1.1	29.8	19.4	1.3	1.1	-6.68	0.04	0.61	1.16	0.03	0.00
	20	-1.90	-0.08	2.03	2.55	0.32	0.03	-24.6	-2.0	37.8	25.1	2.4	2.0	-6.84	0.05	0.63	1.17	0.02	0.00
11	5	-0.09	-0.04	-0.14	0.60	0.15	0.02	-6.0	-0.2	12.0	8.2	0.3	0.2	-3.99	-0.13	0.40	1.15	0.04	-0.00
	10	-0.21	-0.06	-0.04	0.79	0.18	0.02	-8.3	-0.3	14.9	10.6	0.3	0.3	-3.99	-0.12	0.40	1.15	0.03	0.00
	15	-0.41	-0.07	0.17	1.04	0.22	0.03	-10.8	-0.4	17.9	13.0	0.3	0.4	-3.97	-0.12	0.40	1.16	0.04	0.00
	20	-0.71	-0.08	0.55	1.38	0.25	0.04	-13.9	-0.5	21.2	15.7	0.4	0.6	-3.98	-0.12	0.40	1.16	0.04	0.00
12	5	-0.00	-0.03	0.29	0.21	0.10	0.02	-3.4	-0.1	10.6	4.0	0.2	0.2	-1.76	-0.20	0.27	1.15	0.05	-0.00
	10	-0.04	-0.05	0.25	0.27	0.15	0.03	-4.1	-0.2	11.4	4.6	0.3	0.2	-1.79	-0.20	0.26	1.15	0.05	-0.00
	15	-0.10	-0.06	0.29	0.34	0.18	0.04	-4.7	-0.3	12.1	5.1	0.3	0.3	-1.80	-0.20	0.26	1.15	0.05	-0.00
	20	-0.19	-0.07	0.38	0.43	0.21	0.04	-5.3	-0.3	12.8	5.7	0.4	0.3	-1.79	-0.21	0.25	1.16	0.05	-0.00
13	5	-0.02	-0.03	-0.11	0.27	0.09	0.02	-3.8	-0.1	8.3	4.9	0.1	0.1	-3.55	-0.10	0.37	1.13	0.03	0.00
	10	-0.06	-0.04	-0.07	0.34	0.12	0.03	-4.6	-0.1	9.5	5.8	0.1	0.2	-3.58	-0.09	0.37	1.14	0.03	0.00
	15	-0.13	-0.05	-0.00	0.42	0.14	0.03	-5.4	-0.1	10.6	6.6	0.1	0.2	-3.58	-0.09	0.37	1.14	0.03	0.00
	20	-0.21	-0.06	0.10	0.51	0.16	0.04	-6.2	-0.1	11.6	7.4	0.1	0.2	-3.57	-0.09	0.37	1.14	0.03	0.00
14	5	-0.00	-0.03	-0.11	0.27	0.08	0.02	-4.0	-0.1	8.5	5.3	0.1	0.1	-2.91	-0.10	0.34	1.13	0.02	-0.00
	10	-0.05	-0.04	-0.07	0.35	0.11	0.03	-5.0	-0.1	9.9	6.4	0.1	0.1	-2.92	-0.10	0.34	1.14	0.03	0.00
	15	-0.12	-0.05	-0.00	0.44	0.14	0.04	-5.9	-0.1	11.0	7.3	0.1	0.2	-2.91	-0.10	0.33	1.14	0.03	0.00
	20	-0.20	-0.06	0.10	0.53	0.16	0.04	-6.9	-0.1	12.2	8.2	0.0	0.2	-2.90	-0.09	0.33	1.15	0.03	0.00
15	5	0.01	-0.03	-0.07	0.32	0.08	0.02	-3.0	-0.2	7.3	4.4	0.2	0.2	-2.51	-0.20	0.27	1.13	0.04	-0.00
	10	-0.01	-0.04	-0.09	0.38	0.11	0.02	-3.6	-0.2	8.1	5.0	0.2	0.3	-2.49	-0.21	0.26	1.13	0.04	-0.00
	15	-0.04	-0.05	-0.08	0.43	0.13	0.03	-4.2	-0.3	8.6	5.5	0.2	0.4	-2.44	-0.21	0.25	1.14	0.04	0.00
	20	-0.07	-0.07	-0.06	0.50	0.16	0.04	-4.7	-0.4	9.0	5.9	0.3	0.5	-2.41	-0.22	0.25	1.14	0.04	0.00
16	5	0.04	-0.03	1.07	0.13	0.06	0.02	-3.1	-0.1	13.7	3.8	0.2	0.1	-1.51	-0.24	0.35	1.16	0.04	-0.00
	10	0.02	-0.04	1.10	0.17	0.10	0.03	-3.9	-0.1	14.5	4.3	0.2	0.1	-1.49	-0.25	0.34	1.16	0.04	-0.00
	15	-0.02	-0.06	1.20	0.22	0.14	0.04	-4.7	-0.1	15.3	4.9	0.2	0.1	-1.50	-0.25	0.34	1.16	0.04	-0.00
	20	-0.08	-0.07	1.31	0.27	0.17	0.05	-5.4	-0.1	15.9	5.3	0.3	0.1	-1.52	-0.26	0.33	1.16	0.04	-0.00
17	5	0.05	-0.03	0.58	0.11	0.07	0.02	-2.4	-0.1	12.2	2.8	0.2	0.1	-1.76	-0.36	0.24	1.16	0.04	-0.00
	10	0.04	-0.04	0.61	0.13	0.12	0.03	-2.9	-0.1	12.7	3.2	0.3	0.1	-1.69	-0.37	0.22	1.16	0.05	-0.00
	15	0.01	-0.05	0.61	0.16	0.16	0.04	-3.4	-0.1	13.1	3.5	0.3	0.1	-1.70	-0.38	0.22	1.16	0.05	-0.00
	20	-0.03	-0.06	0.69	0.20	0.19	0.04	-3.9	-0.1	13.6	3.9	0.3	0.1	-1.72	-0.39	0.21	1.16	0.05	-0.00
18	5	-0.02	-0.02	0.41	0.17	0.06	0.02	-2.8	-0.1	10.1	3.5	0.1	0.1	-3.35	-0.08	0.40	1.14	0.02	-0.00
	10	-0.06	-0.03	0.46	0.22	0.09	0.02	-3.3	-0.1	11.1	4.0	0.1	0.1	-3.34	-0.08	0.39	1.14	0.03	-0.00
	15	-0.11	-0.04	0.50	0.26	0.11	0.03	-3.8	-0.1	11.8	4.4	0.0	0.1	-3.36	-0.08	0.39	1.15	0.03	-0.00
	20	-0.18	-0.04	0.57	0.32	0.14	0.03	-4.4	-0.1	12.3	4.7	0.0	0.1	-3.37	-0.08	0.38	1.15	0.03	0.00

TABLE A(III)-32 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.01	-0.03	0.11	0.20	0.09	0.02	-3.6	-0.1	9.8	4.5	0.1	0.1	-2.54	-0.11	0.31	1.14	0.03	-0.00
	10	-0.06	-0.04	0.12	0.25	0.12	0.03	-4.4	-0.1	10.7	5.1	0.1	0.1	-2.56	-0.11	0.31	1.14	0.03	-0.00
	15	-0.12	-0.05	0.15	0.31	0.15	0.04	-5.1	-0.1	11.4	5.7	0.1	0.1	-2.58	-0.12	0.31	1.15	0.03	-0.00
	20	-0.18	-0.06	0.22	0.38	0.18	0.05	-5.8	-0.2	12.1	6.2	0.1	0.1	-2.58	-0.12	0.31	1.15	0.03	-0.00
20	5	0.02	-0.03	-0.03	0.25	0.09	0.02	-3.7	-0.1	10.0	4.9	0.1	0.1	-2.52	-0.14	0.27	1.14	0.03	-0.00
	10	-0.02	-0.04	-0.05	0.31	0.13	0.03	-4.6	-0.1	10.9	5.8	0.1	0.2	-2.53	-0.14	0.26	1.14	0.03	-0.00
	15	-0.08	-0.05	-0.00	0.38	0.16	0.04	-5.5	-0.2	11.7	6.6	0.1	0.2	-2.51	-0.14	0.26	1.15	0.03	-0.00
	20	-0.16	-0.07	0.10	0.48	0.19	0.05	-6.5	-0.2	12.7	7.5	0.1	0.2	-2.51	-0.14	0.26	1.15	0.03	-0.00
21	5	0.01	-0.03	-0.02	0.27	0.09	0.02	-3.3	-0.1	9.0	4.7	0.1	0.1	-2.56	-0.14	0.27	1.13	0.04	-0.00
	10	-0.03	-0.04	-0.05	0.33	0.12	0.03	-4.2	-0.2	9.8	5.5	0.1	0.2	-2.58	-0.13	0.27	1.14	0.04	-0.00
	15	-0.08	-0.05	-0.03	0.40	0.15	0.04	-4.9	-0.2	10.4	6.2	0.1	0.2	-2.56	-0.14	0.26	1.14	0.04	-0.00
	20	-0.14	-0.06	0.03	0.48	0.18	0.04	-5.7	-0.3	11.0	6.8	0.2	0.3	-2.53	-0.14	0.26	1.15	0.04	0.00
25	5	0.04	-0.03	0.39	0.19	0.07	0.02	-2.5	-0.1	9.4	3.5	0.2	0.1	-2.15	-0.19	0.32	1.14	0.04	-0.00
	10	0.02	-0.04	0.39	0.23	0.10	0.03	-3.1	-0.1	9.8	4.0	0.2	0.1	-2.17	-0.19	0.32	1.15	0.04	-0.00
	15	-0.01	-0.05	0.40	0.27	0.13	0.03	-3.7	-0.2	10.2	4.4	0.3	0.2	-2.18	-0.19	0.32	1.15	0.04	-0.00
	20	-0.06	-0.06	0.45	0.32	0.16	0.04	-4.2	-0.2	10.6	4.8	0.3	0.2	-2.20	-0.19	0.32	1.15	0.04	-0.00
26	5	-0.03	-0.03	0.14	0.34	0.09	0.01	-2.9	-0.2	7.9	4.1	0.3	0.2	-3.31	-0.15	0.45	1.12	0.05	0.00
	10	-0.06	-0.04	0.11	0.40	0.13	0.02	-3.5	-0.3	8.3	4.6	0.4	0.4	-3.30	-0.15	0.44	1.13	0.05	0.00
	15	-0.10	-0.06	0.11	0.47	0.16	0.03	-3.9	-0.4	8.6	4.9	0.5	0.5	-3.32	-0.15	0.43	1.13	0.05	0.00
	20	-0.16	-0.07	0.15	0.55	0.18	0.04	-4.2	-0.5	9.1	5.1	0.6	0.6	-3.34	-0.16	0.44	1.14	0.05	0.00
27	5	-0.06	-0.04	0.03	0.67	0.09	-0.01	-3.5	-0.3	6.7	5.1	0.5	0.4	-3.94	-0.32	0.42	1.13	0.05	0.00
	10	-0.11	-0.05	0.09	0.83	0.12	-0.01	-4.2	-0.5	7.4	5.6	0.7	0.7	-3.85	-0.33	0.41	1.14	0.05	0.00
	15	-0.17	-0.07	0.16	1.01	0.15	0.00	-4.7	-0.8	7.6	5.9	1.0	1.0	-3.67	-0.36	0.39	1.14	0.05	0.00
	20	-0.25	-0.09	0.23	1.17	0.18	0.01	-4.9	-1.2	7.4	5.8	1.3	1.4	-3.64	-0.37	0.39	1.15	0.06	0.00

TABLE A(III)-33. FALL PLOW SOYBEANS, FALL FERTILIZATION (B SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.09	-0.04	5.59	0.39	-0.19	0.03	-6.2	-0.1	42.5	8.1	0.7	0.1	-0.04	-0.19	0.05	1.17	-0.00	-0.00
	10	-0.39	-0.05	7.83	0.71	-0.24	0.04	-9.0	-0.2	52.6	10.6	0.9	0.2	-0.04	-0.19	0.05	1.17	-0.00	-0.00
	15	-0.79	-0.06	10.19	1.12	-0.30	0.05	-13.2	-0.3	63.4	14.2	1.2	0.3	-0.06	-0.19	0.05	1.18	-0.00	-0.00
	20	-1.41	-0.07	12.68	1.71	-0.32	0.06	-20.5	-0.5	78.5	20.1	1.8	0.5	-0.10	-0.18	0.06	1.18	-0.00	-0.00
2	5	-0.01	-0.04	5.62	0.12	-0.17	0.03	-4.3	-0.1	33.9	5.3	0.9	0.1	0.04	-0.22	0.05	1.18	0.00	-0.00
	10	-0.13	-0.05	6.83	0.25	-0.19	0.04	-6.2	-0.2	40.0	6.8	1.3	0.2	0.04	-0.21	0.05	1.18	0.00	-0.00
	15	-0.31	-0.06	8.07	0.43	-0.21	0.05	-8.5	-0.3	45.9	8.5	1.6	0.3	0.06	-0.21	0.05	1.18	0.00	-0.00
	20	-0.56	-0.07	9.17	0.66	-0.20	0.06	-11.2	-0.5	51.2	10.4	2.0	0.4	0.04	-0.21	0.05	1.18	0.00	-0.00
3	5	0.02	-0.02	3.29	0.05	-0.10	0.01	-1.4	-0.0	18.6	2.0	0.6	0.1	-0.05	-0.25	0.05	1.17	-0.00	-0.00
	10	0.02	-0.02	3.82	0.06	-0.12	0.02	-1.7	-0.1	19.6	2.2	0.8	0.1	-0.01	-0.26	0.05	1.17	-0.00	-0.00
	15	0.01	-0.03	4.26	0.08	-0.13	0.03	-2.0	-0.1	19.8	2.3	0.9	0.1	-0.00	-0.27	0.05	1.17	-0.00	-0.00
	20	-0.01	-0.04	4.67	0.09	-0.14	0.03	-2.2	-0.1	19.8	2.5	0.9	0.1	0.02	-0.27	0.05	1.17	-0.00	-0.00
4	5	0.05	-0.03	4.42	0.16	-0.19	0.03	-3.0	-0.1	23.4	4.1	1.0	0.2	-0.17	-0.30	0.07	1.17	-0.00	-0.00
	10	-0.01	-0.05	5.70	0.25	-0.26	0.03	-3.7	-0.2	26.7	4.9	1.4	0.2	-0.12	-0.31	0.08	1.17	-0.00	-0.00
	15	-0.09	-0.05	6.93	0.37	-0.31	0.04	-4.7	-0.3	29.2	5.7	1.8	0.3	-0.10	-0.32	0.08	1.17	-0.00	-0.00
	20	-0.21	-0.07	8.16	0.51	-0.36	0.05	-5.6	-0.4	30.6	6.4	2.3	0.4	-0.08	-0.32	0.08	1.17	-0.00	-0.00
5	5	0.08	-0.03	3.66	0.08	-0.12	0.02	-2.1	-0.1	19.8	3.2	0.8	0.1	-0.49	-0.39	0.12	1.17	-0.00	-0.00
	10	0.07	-0.04	4.36	0.12	-0.16	0.03	-2.7	-0.1	22.1	3.7	1.0	0.1	-0.46	-0.39	0.12	1.17	-0.00	-0.00
	15	0.04	-0.05	5.05	0.17	-0.18	0.04	-3.2	-0.2	23.6	4.1	1.3	0.2	-0.44	-0.41	0.12	1.17	-0.00	-0.00
	20	0.00	-0.06	5.68	0.22	-0.21	0.05	-3.8	-0.2	24.6	4.5	1.6	0.3	-0.45	-0.41	0.13	1.17	-0.00	-0.00
6	5	-0.19	-0.04	7.69	0.58	-0.51	0.02	-7.6	-0.2	41.2	9.7	1.4	0.3	-0.02	-0.35	0.06	1.18	-0.00	-0.00
	10	-0.60	-0.05	11.16	1.10	-0.71	0.01	-11.9	-0.5	53.9	13.8	2.2	0.5	0.21	-0.37	0.07	1.18	-0.00	-0.00
	15	-1.26	-0.04	14.59	1.82	-0.87	0.00	-18.1	-0.8	66.5	19.1	2.9	0.8	0.25	-0.37	0.07	1.18	-0.00	-0.00
	20	-2.26	-0.03	18.15	2.79	-1.00	-0.02	-26.5	-1.6	80.0	26.0	4.4	1.5	0.28	-0.37	0.07	1.18	-0.00	-0.00
7	5	-0.10	-0.04	6.74	0.51	-0.44	0.02	-5.2	-0.2	24.8	7.0	1.1	0.3	-0.77	-0.31	0.12	1.17	-0.01	-0.00
	10	-0.35	-0.05	9.08	0.87	-0.59	0.02	-7.3	-0.4	30.7	9.1	1.9	0.5	-0.69	-0.33	0.13	1.17	-0.01	-0.00
	15	-0.77	-0.05	11.61	1.37	-0.74	0.01	-9.9	-0.7	36.1	11.5	2.6	0.8	-0.65	-0.33	0.14	1.17	-0.01	-0.00
	20	-1.30	-0.05	13.82	1.95	-0.84	0.00	-13.1	-1.3	41.1	14.4	3.6	1.3	-0.65	-0.34	0.14	1.17	-0.01	-0.00
8	5	0.03	-0.03	3.26	0.15	-0.15	0.02	-2.4	-0.1	15.9	3.5	0.6	0.1	-1.20	-0.29	0.15	1.16	-0.01	-0.00
	10	-0.00	-0.04	3.89	0.21	-0.18	0.03	-2.9	-0.1	17.6	4.0	0.9	0.2	-1.19	-0.29	0.15	1.16	-0.01	-0.00
	15	-0.05	-0.04	4.44	0.28	-0.20	0.04	-3.5	-0.2	18.8	4.4	1.1	0.2	-1.17	-0.30	0.15	1.16	-0.01	-0.00
	20	-0.11	-0.05	5.03	0.35	-0.23	0.04	-3.9	-0.2	19.7	4.8	1.4	0.3	-1.17	-0.31	0.16	1.16	-0.01	-0.00
9	5	-0.47	-0.04	6.23	1.17	-0.42	-0.01	-10.5	-0.5	37.2	13.3	1.8	0.6	-6.61	-0.05	0.11	1.16	-0.01	0.00
	10	-1.05	-0.04	8.01	1.86	-0.48	-0.02	-18.1	-1.1	47.5	20.0	2.7	1.2	-6.94	-0.01	0.11	1.16	-0.01	0.00
	15	-2.12	-0.03	10.50	2.95	-0.53	-0.04	-26.0	-2.3	53.3	26.3	4.4	2.3	-7.26	0.01	0.11	1.17	-0.01	0.00
	20	-3.73	-0.04	13.25	4.41	-0.53	-0.04	-32.4	-3.5	56.1	31.0	5.8	3.5	-7.51	0.02	0.11	1.17	-0.01	0.00

TABLE A(III)-33 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.29	-0.03	4.26	0.88	-0.25	0.00	-7.4	-0.3	26.8	10.7	1.1	0.4	-6.40	-0.00	0.20	1.15	-0.01	0.00
	10	-0.61	-0.04	5.68	1.34	-0.30	-0.00	-11.4	-0.6	33.2	14.7	1.6	0.7	-6.54	0.02	0.20	1.16	-0.01	0.00
	15	-1.06	-0.05	6.50	1.86	-0.28	0.00	-16.4	-1.0	37.9	19.1	2.2	1.1	-6.68	0.04	0.19	1.16	-0.01	0.00
	20	-1.73	-0.07	7.47	2.52	-0.25	0.02	-23.0	-2.0	44.0	24.8	3.3	2.0	-6.84	0.05	0.18	1.17	-0.01	0.00
11	5	-0.09	-0.04	3.05	0.60	-0.15	0.01	-5.0	-0.1	17.8	8.0	0.6	0.2	-3.99	-0.13	0.28	1.15	-0.01	-0.00
	10	-0.20	-0.05	3.60	0.79	-0.16	0.02	-7.1	-0.2	21.8	10.4	0.8	0.3	-3.99	-0.12	0.28	1.15	-0.01	0.00
	15	-0.37	-0.06	4.21	1.03	-0.18	0.03	-9.5	-0.3	24.9	12.7	0.9	0.4	-3.97	-0.12	0.28	1.16	-0.01	0.00
	20	-0.64	-0.07	4.88	1.36	-0.19	0.04	-12.5	-0.5	28.2	15.5	1.2	0.6	-3.98	-0.12	0.28	1.16	-0.01	0.00
12	5	-0.01	-0.03	2.61	0.21	-0.13	0.02	-2.9	-0.1	13.3	3.9	0.6	0.1	-1.76	-0.20	0.19	1.15	-0.01	-0.00
	10	-0.04	-0.04	3.03	0.27	-0.15	0.03	-3.4	-0.2	15.0	4.5	0.8	0.2	-1.79	-0.20	0.20	1.15	-0.01	-0.00
	15	-0.09	-0.05	3.46	0.34	-0.17	0.04	-3.9	-0.2	16.2	5.0	1.0	0.3	-1.80	-0.20	0.20	1.15	-0.01	-0.00
	20	-0.16	-0.05	3.91	0.43	-0.19	0.04	-4.4	-0.3	17.2	5.5	1.2	0.3	-1.79	-0.21	0.20	1.16	-0.01	-0.00
13	5	-0.02	-0.02	1.96	0.27	-0.07	0.02	-3.1	-0.1	11.8	4.8	0.4	0.1	-3.55	-0.10	0.31	1.13	-0.01	0.00
	10	-0.06	-0.03	2.16	0.34	-0.07	0.03	-3.8	-0.1	13.6	5.6	0.4	0.1	-3.58	-0.09	0.31	1.14	-0.01	0.00
	15	-0.12	-0.04	2.37	0.42	-0.07	0.03	-4.5	-0.1	15.1	6.4	0.5	0.2	-3.58	-0.09	0.31	1.14	-0.01	0.00
	20	-0.18	-0.05	2.57	0.51	-0.07	0.04	-5.3	-0.1	16.4	7.2	0.5	0.2	-3.57	-0.09	0.32	1.14	-0.01	0.00
14	5	-0.01	-0.02	1.90	0.28	-0.06	0.02	-3.3	-0.1	12.2	5.2	0.3	0.1	-2.91	-0.10	0.34	1.13	-0.01	-0.00
	10	-0.05	-0.03	2.11	0.35	-0.06	0.03	-4.1	-0.1	14.3	6.2	0.4	0.1	-2.92	-0.10	0.34	1.14	-0.01	0.00
	15	-0.11	-0.04	2.32	0.43	-0.06	0.03	-5.0	-0.1	15.8	7.1	0.4	0.2	-2.91	-0.10	0.34	1.14	-0.01	0.00
	20	-0.18	-0.05	2.54	0.53	-0.06	0.04	-5.9	-0.1	17.3	8.1	0.5	0.2	-2.90	-0.09	0.34	1.15	-0.01	0.00
15	5	0.00	-0.03	1.70	0.32	-0.08	0.01	-2.6	-0.1	8.7	4.3	0.5	0.2	-2.51	-0.20	0.24	1.13	-0.01	-0.00
	10	-0.01	-0.04	1.96	0.38	-0.09	0.02	-3.2	-0.2	9.6	5.0	0.7	0.3	-2.49	-0.21	0.24	1.13	-0.01	-0.00
	15	-0.04	-0.05	2.16	0.44	-0.09	0.03	-3.7	-0.3	10.1	5.4	0.8	0.4	-2.44	-0.21	0.24	1.14	-0.01	0.00
	20	-0.07	-0.06	2.38	0.50	-0.10	0.04	-4.2	-0.3	10.4	5.8	1.0	0.5	-2.41	-0.22	0.24	1.14	-0.01	0.00
16	5	0.04	-0.03	3.08	0.13	-0.07	0.02	-2.2	-0.1	18.9	3.6	0.5	0.1	-1.51	-0.24	0.20	1.16	-0.00	-0.00
	10	0.02	-0.03	3.52	0.17	-0.08	0.03	-2.8	-0.1	21.2	4.1	0.6	0.1	-1.49	-0.25	0.21	1.16	-0.00	-0.00
	15	-0.01	-0.04	3.93	0.21	-0.09	0.04	-3.4	-0.1	22.9	4.6	0.6	0.1	-1.50	-0.25	0.21	1.16	-0.00	-0.00
	20	-0.06	-0.05	4.35	0.27	-0.10	0.05	-4.0	-0.1	24.0	5.1	0.8	0.1	-1.52	-0.26	0.21	1.16	-0.00	-0.00
17	5	0.04	-0.02	2.84	0.11	-0.07	0.02	-1.6	-0.0	16.3	2.7	0.5	0.1	-1.76	-0.36	0.20	1.16	-0.00	-0.00
	10	0.03	-0.03	3.27	0.13	-0.08	0.03	-2.0	-0.1	18.1	3.0	0.6	0.1	-1.69	-0.37	0.20	1.16	-0.00	-0.00
	15	0.01	-0.04	3.68	0.16	-0.09	0.03	-2.3	-0.1	19.3	3.3	0.7	0.1	-1.70	-0.38	0.21	1.16	-0.00	-0.00
	20	-0.02	-0.05	4.06	0.20	-0.10	0.04	-2.8	-0.1	20.3	3.7	0.8	0.1	-1.72	-0.39	0.21	1.16	-0.00	-0.00
18	5	-0.03	-0.02	2.33	0.17	-0.07	0.02	-2.2	-0.0	13.1	3.4	0.3	0.1	-3.35	-0.08	0.30	1.14	-0.01	-0.00
	10	-0.06	-0.02	2.54	0.22	-0.08	0.02	-2.6	-0.1	14.5	3.8	0.3	0.1	-3.34	-0.08	0.30	1.14	-0.01	-0.00
	15	-0.10	-0.03	2.73	0.26	-0.08	0.03	-3.1	-0.1	15.6	4.2	0.4	0.1	-3.36	-0.08	0.31	1.15	-0.01	-0.00
	20	-0.15	-0.03	2.94	0.31	-0.08	0.03	-3.6	-0.1	16.5	4.6	0.5	0.1	-3.37	-0.08	0.31	1.15	-0.01	0.00

TABLE A(III)-33 (CONT)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
19	5	-0.01	-0.03	2.15	0.20	-0.05	0.02	-3.0	-0.1	13.2	4.3	0.3	0.1	-2.54	-0.11	0.32	1.14	-0.01	-0.00
	10	-0.06	-0.04	2.37	0.25	-0.05	0.03	-3.6	-0.1	14.7	5.0	0.4	0.1	-2.56	-0.11	0.32	1.14	-0.01	-0.00
	15	-0.11	-0.04	2.55	0.31	-0.05	0.04	-4.2	-0.1	16.0	5.5	0.4	0.1	-2.58	-0.12	0.33	1.15	-0.01	-0.00
	20	-0.16	-0.05	2.74	0.37	-0.05	0.05	-4.9	-0.1	17.1	6.1	0.5	0.1	-2.58	-0.12	0.33	1.15	-0.01	-0.00
20	5	0.01	-0.03	2.08	0.25	-0.07	0.02	-3.1	-0.1	12.7	4.8	0.4	0.1	-2.52	-0.14	0.29	1.14	-0.01	-0.00
	10	-0.02	-0.04	2.36	0.31	-0.08	0.03	-3.9	-0.1	14.6	5.6	0.5	0.1	-2.53	-0.14	0.29	1.14	-0.01	-0.00
	15	-0.07	-0.05	2.62	0.38	-0.09	0.04	-4.7	-0.1	16.2	6.4	0.5	0.2	-2.51	-0.14	0.29	1.15	-0.01	-0.00
	20	-0.14	-0.05	2.87	0.47	-0.09	0.04	-5.5	-0.1	17.9	7.3	0.6	0.2	-2.51	-0.14	0.29	1.15	-0.01	-0.00
21	5	0.00	-0.03	1.83	0.27	-0.07	0.02	-2.9	-0.1	10.8	4.6	0.4	0.1	-2.56	-0.14	0.27	1.13	-0.01	-0.00
	10	-0.03	-0.04	2.07	0.33	-0.07	0.03	-3.6	-0.1	12.4	5.4	0.5	0.2	-2.58	-0.13	0.27	1.14	-0.01	-0.00
	15	-0.07	-0.04	2.28	0.40	-0.08	0.03	-4.2	-0.2	13.7	6.0	0.6	0.2	-2.56	-0.14	0.27	1.14	-0.01	-0.00
	20	-0.13	-0.05	2.50	0.48	-0.08	0.04	-4.9	-0.2	14.7	6.7	0.7	0.3	-2.53	-0.14	0.27	1.15	-0.01	0.00
25	5	0.04	-0.03	2.41	0.19	-0.10	0.02	-2.0	-0.1	12.4	3.4	0.4	0.1	-2.15	-0.19	0.25	1.14	-0.01	-0.00
	10	0.01	-0.03	2.70	0.23	-0.11	0.03	-2.4	-0.1	13.7	3.9	0.6	0.1	-2.17	-0.19	0.25	1.15	-0.01	-0.00
	15	-0.01	-0.04	2.98	0.27	-0.12	0.03	-2.9	-0.1	14.6	4.3	0.7	0.2	-2.18	-0.19	0.25	1.15	-0.01	-0.00
	20	-0.05	-0.05	3.25	0.32	-0.13	0.04	-3.3	-0.2	15.2	4.6	0.8	0.2	-2.20	-0.19	0.25	1.15	-0.01	-0.00
26	5	-0.03	-0.03	2.21	0.34	-0.14	0.01	-2.5	-0.1	9.5	4.0	0.6	0.2	-3.31	-0.15	0.12	1.12	-0.01	0.00
	10	-0.06	-0.04	2.46	0.40	-0.15	0.02	-3.0	-0.2	10.3	4.5	0.9	0.3	-3.30	-0.15	0.12	1.13	-0.01	0.00
	15	-0.10	-0.05	2.72	0.47	-0.16	0.03	-3.3	-0.4	10.4	4.8	1.1	0.5	-3.32	-0.15	0.13	1.13	-0.01	-0.00
	20	-0.15	-0.06	2.94	0.55	-0.16	0.04	-3.8	-0.5	10.4	5.0	1.3	0.6	-3.34	-0.16	0.13	1.14	-0.01	0.00
27	5	-0.05	-0.03	2.64	0.67	-0.18	-0.01	-3.0	-0.2	9.6	5.0	0.9	0.4	-3.94	-0.32	0.14	1.13	-0.01	0.00
	10	-0.10	-0.04	3.27	0.83	-0.22	-0.01	-3.6	-0.5	10.0	5.5	1.3	0.7	-3.85	-0.33	0.13	1.14	-0.01	0.00
	15	-0.16	-0.06	3.91	1.01	-0.25	-0.00	-4.1	-0.8	9.6	5.8	1.7	1.0	-3.67	-0.36	0.13	1.14	-0.01	0.00
	20	-0.22	-0.08	4.37	1.17	-0.26	0.01	-4.4	-1.2	8.5	5.7	2.2	1.4	-3.64	-0.37	0.12	1.15	-0.01	0.00

TABLE A(III)-34. FALL PLOW SOYBEANS (C SOILS ONLY)

REGION	AW	A	B	A'	B'
1	5	0.69	13.29	-0.63	35.52
	10	0.62	13.13	-0.51	23.98
	15	0.57	12.69	-0.43	15.84
	20	0.51	12.29	-0.38	8.85
2	5	1.09	16.05	-1.05	38.01
	10	1.02	16.00	-0.93	27.86
	15	0.96	15.84	-0.82	20.57
	20	0.89	15.69	-0.75	15.36
3	5	1.50	20.28	-1.49	47.80
	10	1.54	19.93	-1.53	42.39
	15	1.54	19.74	-1.54	39.30
	20	1.53	19.49	-1.53	36.81
4	5	1.60	13.35	-1.57	46.03
	10	1.63	12.95	-1.53	36.72
	15	1.60	12.67	-1.44	30.23
	20	1.56	12.37	-1.44	25.39
5	5	1.54	16.23	-1.52	46.35
	10	1.57	16.03	-1.49	38.66
	15	1.56	15.72	-1.49	33.64
	20	1.56	15.43	-1.48	29.58
6	5	1.12	7.18	-1.03	36.94
	10	1.06	6.86	-0.81	23.21
	15	0.98	6.71	-0.65	14.92
	20	0.90	6.51	-0.54	8.83
7	5	1.60	7.20	-1.53	44.67
	10	1.64	6.76	-1.41	31.68
	15	1.61	6.35	-1.22	23.19
	20	1.57	6.05	-1.06	16.58
8	5	1.62	16.42	-1.58	47.88
	10	1.68	16.06	-1.59	40.03
	15	1.70	15.74	-1.56	34.78
	20	1.70	15.35	-1.56	30.89
9	5	1.49	5.18	-1.37	38.81
	10	1.39	4.73	-1.03	23.65
	15	1.33	4.36	-0.94	15.74
	20	1.26	4.05	-0.85	10.62
10	5	1.45	11.51	-1.38	43.21
	10	1.41	11.21	-1.14	29.10
	15	1.33	10.63	-1.01	20.73
	20	1.28	10.07	-0.89	13.92
11	5	1.31	18.29	-1.26	44.68
	10	1.25	18.06	-1.04	32.34
	15	1.23	17.55	-0.91	24.71
	20	1.20	17.03	-0.82	18.76
12	5	1.70	17.26	-1.67	49.86
	10	1.76	16.91	-1.68	41.67
	15	1.79	16.61	-1.64	36.12
	20	1.79	16.18	-1.58	31.72
13	5	1.23	29.36	-1.19	42.36
	10	1.22	29.26	-1.08	33.79
	15	1.20	28.99	-0.95	28.10
	20	1.18	28.66	-0.85	23.63
14	5	1.06	30.32	-1.02	39.71
	10	1.07	30.05	-0.90	30.99
	15	1.06	29.72	-0.80	25.40
	20	1.01	29.36	-0.71	21.00
15	5	1.78	23.50	-1.76	45.86
	10	1.82	23.11	-1.75	38.20
	15	1.84	22.70	-1.76	33.72
	20	1.84	22.30	-1.77	30.42
16	5	1.12	21.32	-1.09	44.55
	10	1.10	21.09	-1.02	37.28
	15	1.08	20.86	-0.97	32.07
	20	1.07	20.56	-0.98	28.35
17	5	1.34	20.23	-1.32	46.89
	10	1.36	19.99	-1.30	39.98
	15	1.34	19.72	-1.28	35.24
	20	1.34	19.45	-1.27	31.19
18	5	0.95	29.66	-0.94	42.44
	10	0.94	29.49	-0.90	35.99
	15	0.92	29.22	-0.86	31.46
	20	0.90	28.85	-0.86	27.81
19	5	1.13	25.98	-1.10	42.15
	10	1.13	25.77	-1.04	35.15
	15	1.10	25.51	-0.97	30.35
	20	1.08	25.17	-0.95	26.59
20	5	1.16	26.38	-1.13	42.34
	10	1.17	26.13	-1.06	33.89
	15	1.16	25.84	-0.98	28.25
	20	1.12	25.56	-0.88	23.60
21	5	1.37	26.47	-1.35	43.38
	10	1.41	26.13	-1.32	35.28
	15	1.40	25.75	-1.26	29.86
	20	1.38	25.41	-1.22	25.76
25	5	1.52	22.22	-1.50	48.96
	10	1.53	22.05	-1.48	41.61
	15	1.55	21.72	-1.50	36.73
	20	1.55	21.37	-1.49	32.99
26	5	2.23	14.09	-2.21	53.61
	10	2.30	13.61	-2.25	45.53
	15	2.35	13.08	-2.30	41.15
	20	2.36	12.75	-2.32	37.84
27	5	2.58	8.51	-2.56	53.81
	10	2.66	7.82	-2.61	45.33
	15	2.74	7.07	-2.63	40.18
	20	2.79	6.36	-2.66	36.45

TABLE A(III)-35. FALL PLOW SOYBEANS, SPRING FERTILIZATION (C SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.26	-0.03	3.14	0.56	0.07	0.02	-9.7	-0.2	37.0	10.0	0.5	0.2	-0.21	-0.12	0.37	1.17	0.03	-0.00
	10	-0.83	-0.05	4.31	1.07	0.13	0.03	-14.7	-0.3	45.3	13.9	0.7	0.3	-0.21	-0.12	0.37	1.18	0.02	-0.00
	15	-1.58	-0.07	5.84	1.69	0.19	0.05	-22.2	-0.7	59.3	19.8	1.4	0.6	-0.23	-0.11	0.36	1.18	0.02	-0.00
	20	-2.66	-0.09	8.21	2.55	0.25	0.06	-35.9	-1.6	87.5	30.7	3.4	1.4	-0.26	-0.11	0.36	1.18	0.02	-0.00
2	5	-0.07	-0.04	1.65	0.20	0.10	0.03	-6.7	-0.3	31.3	6.5	0.8	0.2	-0.16	-0.15	0.20	1.18	0.04	-0.00
	10	-0.30	-0.06	2.17	0.40	0.17	0.04	-9.7	-0.4	37.1	8.6	1.1	0.4	-0.16	-0.15	0.20	1.18	0.03	-0.00
	15	-0.64	-0.07	2.93	0.67	0.24	0.05	-13.6	-0.7	44.0	11.3	1.8	0.6	-0.16	-0.15	0.19	1.18	0.03	-0.00
	20	-1.07	-0.09	3.97	0.99	0.29	0.06	-17.6	-1.2	52.1	14.2	2.9	0.9	-0.18	-0.15	0.18	1.18	0.03	-0.00
3	5	0.02	-0.02	1.13	0.08	0.06	0.01	-2.6	-0.1	16.0	2.5	0.6	0.1	-0.21	-0.19	0.18	1.17	0.04	-0.00
	10	0.01	-0.03	1.19	0.10	0.10	0.02	-3.1	-0.2	16.7	2.8	0.7	0.1	-0.18	-0.20	0.17	1.17	0.04	-0.00
	15	-0.01	-0.04	1.26	0.12	0.14	0.03	-3.5	-0.2	17.0	3.0	0.7	0.2	-0.17	-0.21	0.17	1.17	0.04	-0.00
	20	-0.05	-0.05	1.36	0.15	0.17	0.03	-3.9	-0.2	17.3	3.1	0.7	0.2	-0.16	-0.21	0.16	1.17	0.04	-0.00
4	5	0.03	-0.04	1.48	0.23	0.07	0.02	-4.6	-0.2	19.5	4.9	0.7	0.2	-0.26	-0.24	0.24	1.17	0.04	-0.00
	10	-0.09	-0.05	1.64	0.37	0.14	0.03	-5.9	-0.4	21.9	5.9	1.1	0.4	-0.23	-0.24	0.23	1.17	0.05	-0.00
	15	-0.26	-0.07	1.95	0.54	0.19	0.04	-7.3	-0.6	24.3	6.9	1.5	0.5	-0.22	-0.25	0.21	1.17	0.05	-0.00
	20	-0.49	-0.09	2.43	0.74	0.25	0.06	-8.5	-1.0	26.0	7.7	2.4	0.9	-0.21	-0.25	0.20	1.18	0.05	-0.00
5	5	0.09	-0.03	0.90	0.13	0.07	0.02	-3.6	-0.2	16.8	3.8	0.6	0.2	-0.64	-0.30	0.19	1.17	0.04	-0.00
	10	0.05	-0.05	1.00	0.19	0.13	0.03	-4.5	-0.3	18.2	4.5	0.8	0.3	-0.62	-0.30	0.18	1.17	0.04	-0.00
	15	-0.01	-0.06	1.12	0.26	0.17	0.04	-5.4	-0.4	19.3	5.0	1.1	0.4	-0.61	-0.31	0.17	1.17	0.04	-0.00
	20	-0.10	-0.07	1.33	0.34	0.22	0.05	-6.2	-0.6	20.2	5.5	1.4	0.5	-0.62	-0.32	0.17	1.17	0.05	-0.00
6	5	-0.30	-0.04	1.75	0.80	0.15	0.01	-10.8	-0.4	33.5	11.2	0.9	0.4	-0.12	-0.26	0.11	1.18	0.06	-0.00
	10	-1.03	-0.05	2.84	1.54	0.21	0.01	-17.2	-0.9	44.8	16.6	1.8	0.8	-0.01	-0.27	0.08	1.18	0.06	-0.00
	15	-2.14	-0.05	4.90	2.54	0.24	0.00	-26.1	-1.8	61.3	23.8	3.4	1.6	0.00	-0.26	0.07	1.18	0.06	-0.00
	20	-3.66	-0.05	7.83	3.85	0.27	0.00	-37.5	-3.6	83.0	32.9	6.8	3.2	0.01	-0.26	0.07	1.18	0.06	-0.00
7	5	-0.14	-0.05	1.22	0.65	0.12	0.02	-7.0	-0.4	20.9	7.8	0.7	0.4	-0.63	-0.26	0.18	1.17	0.06	-0.00
	10	-0.52	-0.06	1.54	1.10	0.19	0.02	-10.0	-0.8	25.6	10.4	1.4	0.8	-0.58	-0.27	0.16	1.17	0.06	-0.00
	15	-1.10	-0.07	2.33	1.70	0.24	0.02	-13.4	-1.4	30.7	13.3	2.4	1.4	-0.56	-0.28	0.14	1.18	0.06	-0.00
	20	-1.82	-0.09	3.45	2.39	0.30	0.03	-16.9	-2.8	36.2	16.1	4.6	2.6	-0.56	-0.28	0.14	1.18	0.06	-0.00
8	5	0.03	-0.03	0.66	0.21	0.08	0.02	-3.7	-0.2	13.8	4.1	0.5	0.2	-1.08	-0.23	0.21	1.16	0.04	-0.00
	10	-0.03	-0.04	0.70	0.29	0.12	0.03	-4.6	-0.3	15.2	4.8	0.6	0.3	-1.07	-0.24	0.20	1.17	0.04	-0.00
	15	-0.11	-0.06	0.79	0.38	0.17	0.04	-5.3	-0.4	16.3	5.4	0.8	0.4	-1.05	-0.24	0.19	1.17	0.05	-0.00
	20	-0.21	-0.07	0.94	0.48	0.21	0.05	-6.0	-0.5	17.1	5.8	1.1	0.5	-1.05	-0.25	0.19	1.17	0.05	-0.00
9	5	-0.62	-0.04	0.21	1.55	0.24	-0.02	-13.7	-0.8	28.5	14.7	1.4	0.8	-5.53	-0.11	0.51	1.16	0.04	0.00
	10	-1.53	-0.04	1.56	2.54	0.26	-0.04	-22.6	-1.8	41.4	22.4	2.7	1.7	-5.72	-0.09	0.52	1.17	0.03	0.00
	15	-3.18	-0.04	4.01	4.11	0.27	-0.05	-30.7	-3.5	52.3	28.8	5.3	3.3	-5.92	-0.08	0.54	1.17	0.03	0.00
	20	-5.42	-0.08	7.32	6.09	0.33	-0.02	-38.5	-3.8	62.3	34.2	6.3	3.9	-6.16	-0.07	0.57	1.17	0.03	0.00

TABLE A(III)-35 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.36	-0.04	0.04	1.11	0.17	-0.00	-10.2	-0.5	20.2	12.2	0.8	0.6	-5.59	-0.04	0.52	1.16	0.03	0.00
	10	-0.84	-0.05	0.56	1.71	0.21	0.00	-15.5	-1.1	27.7	17.2	1.4	1.1	-5.71	-0.03	0.53	1.16	0.02	0.00
	15	-1.56	-0.07	1.51	2.46	0.25	0.02	-21.8	-2.1	35.6	22.6	2.6	2.1	-5.81	-0.01	0.53	1.17	0.02	0.00
	20	-2.60	-0.12	2.84	3.44	0.33	0.06	-29.3	-4.5	44.9	28.7	5.5	4.3	-5.96	-0.00	0.55	1.17	0.02	0.00
11	5	-0.14	-0.04	-0.06	0.75	0.11	0.01	-7.2	-0.3	14.3	9.5	0.4	0.4	-3.72	-0.11	0.38	1.15	0.03	0.00
	10	-0.32	-0.05	0.10	1.01	0.15	0.02	-10.6	-0.5	18.6	12.8	0.5	0.6	-3.73	-0.10	0.38	1.16	0.03	0.00
	15	-0.60	-0.07	0.41	1.35	0.19	0.04	-14.4	-0.8	23.2	16.2	0.7	0.8	-3.71	-0.10	0.38	1.16	0.03	0.00
	20	-1.03	-0.10	0.92	1.82	0.24	0.06	-19.3	-1.3	28.6	20.5	1.2	1.3	-3.70	-0.10	0.38	1.17	0.03	0.00
12	5	-0.02	-0.03	0.35	0.28	0.09	0.02	-4.0	-0.2	12.0	4.6	0.4	0.2	-1.70	-0.16	0.26	1.16	0.04	-0.00
	10	-0.08	-0.04	0.34	0.35	0.13	0.03	-4.8	-0.3	13.1	5.3	0.5	0.3	-1.72	-0.16	0.25	1.16	0.04	-0.00
	15	-0.16	-0.06	0.41	0.45	0.17	0.04	-5.6	-0.5	14.0	5.9	0.7	0.4	-1.73	-0.17	0.25	1.16	0.04	-0.00
	20	-0.27	-0.07	0.54	0.56	0.20	0.05	-6.4	-0.6	15.0	6.6	0.8	0.6	-1.73	-0.17	0.24	1.16	0.04	0.00
13	5	-0.04	-0.03	-0.07	0.35	0.07	0.02	-4.7	-0.2	10.3	5.9	0.3	0.2	-3.36	-0.08	0.35	1.14	0.02	0.00
	10	-0.11	-0.04	-0.01	0.44	0.10	0.03	-6.1	-0.3	12.3	7.3	0.3	0.3	-3.38	-0.08	0.35	1.15	0.02	0.00
	15	-0.20	-0.05	0.09	0.55	0.12	0.03	-7.4	-0.3	14.2	8.6	0.3	0.3	-3.38	-0.08	0.35	1.15	0.02	0.00
	20	-0.31	-0.06	0.24	0.68	0.15	0.05	-9.0	-0.4	16.1	9.9	0.3	0.4	-3.37	-0.08	0.35	1.15	0.02	0.00
14	5	-0.03	-0.03	-0.06	0.36	0.07	0.02	-5.1	-0.2	10.8	6.5	0.2	0.2	-2.78	-0.08	0.33	1.14	0.02	0.00
	10	-0.11	-0.04	0.00	0.47	0.09	0.03	-6.8	-0.2	13.2	8.2	0.2	0.3	-2.79	-0.08	0.33	1.15	0.02	0.00
	15	-0.21	-0.05	0.12	0.59	0.12	0.04	-8.4	-0.3	15.3	9.8	0.2	0.3	-2.79	-0.08	0.32	1.15	0.02	0.00
	20	-0.33	-0.07	0.27	0.73	0.15	0.05	-10.3	-0.4	17.6	11.5	0.2	0.4	-2.77	-0.07	0.32	1.16	0.02	0.00
15	5	-0.00	-0.03	-0.04	0.41	0.07	0.01	-3.6	-0.3	8.6	5.0	0.3	0.3	-2.45	-0.17	0.26	1.14	0.03	-0.00
	10	-0.03	-0.04	-0.05	0.49	0.10	0.02	-4.4	-0.4	9.7	5.8	0.4	0.5	-2.43	-0.17	0.26	1.14	0.03	0.00
	15	-0.08	-0.06	-0.03	0.57	0.13	0.03	-5.1	-0.6	10.4	6.2	0.5	0.7	-2.40	-0.18	0.25	1.15	0.04	0.00
	20	-0.13	-0.08	0.01	0.66	0.16	0.05	-5.7	-0.8	10.7	6.6	0.7	0.9	-2.37	-0.18	0.25	1.15	0.04	0.00
16	5	0.04	-0.03	1.17	0.18	0.05	0.02	-3.9	-0.1	15.8	4.5	0.4	0.1	-1.55	-0.18	0.34	1.16	0.03	-0.00
	10	-0.00	-0.04	1.26	0.23	0.09	0.03	-5.0	-0.2	17.2	5.3	0.4	0.2	-1.54	-0.18	0.34	1.17	0.03	-0.00
	15	-0.07	-0.05	1.42	0.30	0.12	0.04	-6.1	-0.2	18.6	6.1	0.4	0.2	-1.55	-0.18	0.33	1.17	0.03	-0.00
	20	-0.15	-0.07	1.60	0.38	0.16	0.05	-7.1	-0.3	19.7	6.7	0.6	0.3	-1.57	-0.19	0.33	1.17	0.03	-0.00
17	5	0.04	-0.02	0.79	0.15	0.06	0.02	-2.9	-0.1	13.8	3.3	0.4	0.1	-1.72	-0.27	0.25	1.16	0.03	-0.00
	10	0.02	-0.04	0.86	0.19	0.10	0.02	-3.7	-0.2	14.6	3.8	0.4	0.2	-1.68	-0.28	0.24	1.16	0.03	-0.00
	15	-0.02	-0.05	0.93	0.23	0.14	0.03	-4.3	-0.2	15.3	4.3	0.5	0.2	-1.69	-0.28	0.24	1.17	0.03	-0.00
	20	-0.08	-0.06	1.07	0.28	0.18	0.04	-5.1	-0.3	16.2	4.8	0.7	0.2	-1.70	-0.29	0.23	1.17	0.04	-0.00
18	5	-0.05	-0.02	0.57	0.23	0.05	0.01	-3.6	-0.1	12.6	4.4	0.2	0.1	-3.18	-0.06	0.40	1.15	0.02	0.00
	10	-0.11	-0.03	0.67	0.30	0.08	0.02	-4.5	-0.1	14.2	5.1	0.2	0.1	-3.18	-0.06	0.39	1.15	0.02	0.00
	15	-0.19	-0.04	0.77	0.37	0.10	0.03	-5.3	-0.2	15.4	5.7	0.1	0.2	-3.19	-0.06	0.39	1.16	0.02	0.00
	20	-0.28	-0.04	0.90	0.45	0.13	0.03	-6.2	-0.2	16.2	6.3	0.2	0.2	-3.20	-0.06	0.39	1.16	0.02	0.00

TABLE A(III)-35 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.04	-0.03	0.23	0.27	0.07	0.02	-4.6	-0.2	11.9	5.4	0.3	0.2	-2.36	-0.09	0.30	1.15	0.02	-0.00
	10	-0.11	-0.04	0.28	0.35	0.10	0.03	-5.7	-0.2	13.6	6.4	0.2	0.2	-2.37	-0.09	0.30	1.15	0.02	0.00
	15	-0.19	-0.05	0.36	0.43	0.13	0.04	-6.8	-0.3	14.9	7.3	0.2	0.3	-2.39	-0.09	0.30	1.16	0.02	0.00
	20	-0.29	-0.06	0.47	0.52	0.16	0.05	-8.0	-0.3	16.1	8.2	0.2	0.3	-2.39	-0.09	0.30	1.16	0.02	0.00
20	5	-0.01	-0.03	0.05	0.33	0.07	0.02	-4.7	-0.2	12.3	5.9	0.2	0.2	-2.44	-0.11	0.27	1.15	0.03	-0.00
	10	-0.07	-0.04	0.07	0.42	0.11	0.03	-6.2	-0.3	13.9	7.2	0.2	0.3	-2.45	-0.11	0.26	1.15	0.03	-0.00
	15	-0.16	-0.05	0.17	0.53	0.14	0.04	-7.6	-0.3	15.3	8.5	0.3	0.4	-2.44	-0.11	0.26	1.16	0.03	0.00
	20	-0.29	-0.07	0.32	0.66	0.17	0.05	-9.3	-0.4	17.2	10.0	0.3	0.4	-2.45	-0.11	0.26	1.16	0.03	0.00
21	5	-0.01	-0.03	0.05	0.36	0.07	0.02	-4.2	-0.2	10.8	5.5	0.2	0.2	-2.47	-0.11	0.27	1.14	0.03	-0.00
	10	-0.07	-0.04	0.04	0.44	0.11	0.03	-5.4	-0.3	12.0	6.6	0.3	0.4	-2.48	-0.11	0.26	1.15	0.03	0.00
	15	-0.14	-0.05	0.09	0.54	0.14	0.04	-6.4	-0.4	13.0	7.6	0.4	0.5	-2.47	-0.11	0.26	1.15	0.03	0.00
	20	-0.24	-0.07	0.18	0.65	0.17	0.05	-7.6	-0.6	14.0	8.6	0.5	0.6	-2.45	-0.11	0.26	1.16	0.03	0.00
25	5	0.03	-0.03	0.51	0.24	0.06	0.02	-3.2	-0.1	10.7	4.1	0.3	0.2	-2.02	-0.15	0.32	1.15	0.03	-0.00
	10	-0.00	-0.04	0.53	0.30	0.09	0.02	-4.0	-0.2	11.5	4.8	0.4	0.2	-2.04	-0.15	0.31	1.15	0.03	-0.00
	15	-0.05	-0.05	0.57	0.36	0.12	0.03	-4.7	-0.3	12.1	5.3	0.5	0.3	-2.05	-0.15	0.31	1.16	0.03	0.00
	20	-0.11	-0.06	0.66	0.43	0.15	0.04	-5.4	-0.4	12.9	5.8	0.6	0.4	-2.07	-0.15	0.31	1.16	0.03	0.00
26	5	-0.03	-0.03	0.19	0.43	0.08	0.01	-3.3	-0.3	8.6	4.5	0.4	0.3	-2.81	-0.15	0.37	1.14	0.04	0.00
	10	-0.08	-0.04	0.17	0.52	0.11	0.02	-3.9	-0.4	9.1	5.0	0.6	0.5	-2.81	-0.15	0.37	1.14	0.04	0.00
	15	-0.13	-0.06	0.17	0.62	0.15	0.03	-4.3	-0.7	9.6	5.2	0.8	0.7	-2.81	-0.16	0.36	1.15	0.04	0.00
	20	-0.21	-0.08	0.22	0.72	0.18	0.04	-4.6	-0.9	10.2	5.3	1.0	0.9	-2.83	-0.16	0.36	1.15	0.05	0.00
27	5	-0.06	-0.04	-0.00	0.87	0.09	-0.01	-3.9	-0.4	7.2	5.4	0.6	0.5	-3.50	-0.31	0.35	1.14	0.05	0.00
	10	-0.13	-0.05	0.07	1.09	0.12	-0.01	-4.5	-0.8	7.6	5.8	1.0	1.0	-3.40	-0.33	0.34	1.14	0.05	0.00
	15	-0.22	-0.08	0.16	1.33	0.16	0.00	-4.8	-1.3	7.4	5.7	1.4	1.4	-3.24	-0.35	0.33	1.15	0.05	0.00
	20	-0.31	-0.12	0.25	1.53	0.20	0.03	-4.5	-2.0	6.8	5.0	2.1	2.1	-3.19	-0.36	0.32	1.15	0.05	0.00

TABLE A(III)-36. FALL PLOW SOYBEANS, FALL FERTILIZATION (C SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.22	-0.03	7.68	0.56	-0.17	0.02	-7.7	-0.2	48.1	9.7	1.0	0.2	-0.21	-0.12	0.05	1.17	-0.00	-0.00
	10	-0.69	-0.04	10.40	1.04	-0.20	0.03	-12.0	-0.3	60.9	13.4	1.4	0.3	-0.21	-0.12	0.05	1.18	-0.00	-0.00
	15	-1.31	-0.06	13.23	1.64	-0.21	0.05	-19.0	-0.6	76.1	19.2	2.2	0.6	-0.23	-0.11	0.05	1.18	-0.00	-0.00
	20	-2.24	-0.07	16.40	2.48	-0.20	0.06	-32.5	-1.5	101.1	30.1	4.4	1.4	-0.26	-0.11	0.06	1.18	0.00	-0.00
2	5	-0.06	-0.03	7.23	0.20	-0.17	0.03	-5.3	-0.2	36.9	6.2	1.3	0.2	-0.16	-0.15	0.06	1.18	-0.00	-0.00
	10	-0.24	-0.05	8.64	0.39	-0.17	0.04	-8.0	-0.4	44.1	8.3	2.0	0.3	-0.16	-0.15	0.06	1.18	-0.00	-0.00
	15	-0.51	-0.06	10.13	0.64	-0.16	0.05	-11.4	-0.7	51.6	10.9	2.8	0.6	-0.16	-0.15	0.06	1.18	-0.00	-0.00
	20	-0.86	-0.07	11.45	0.95	-0.14	0.06	-15.3	-1.1	58.6	13.7	3.9	0.9	-0.18	-0.15	0.06	1.18	0.00	-0.00
3	5	0.02	-0.02	4.36	0.08	-0.10	0.01	-1.8	-0.1	19.9	2.3	0.9	0.1	-0.21	-0.19	0.06	1.17	-0.00	-0.00
	10	0.01	-0.02	4.95	0.10	-0.12	0.02	-2.2	-0.1	20.8	2.6	1.1	0.1	-0.18	-0.20	0.06	1.17	-0.00	-0.00
	15	-0.00	-0.03	5.43	0.12	-0.12	0.02	-2.5	-0.2	20.7	2.8	1.2	0.1	-0.17	-0.21	0.06	1.17	-0.00	-0.00
	20	-0.03	-0.04	5.87	0.15	-0.12	0.03	-2.9	-0.2	20.5	3.0	1.3	0.2	-0.16	-0.21	0.06	1.17	-0.00	-0.00
4	5	0.03	-0.03	6.08	0.23	-0.21	0.02	-3.5	-0.2	25.0	4.7	1.3	0.2	-0.26	-0.24	0.08	1.17	-0.00	-0.00
	10	-0.07	-0.04	7.62	0.37	-0.27	0.03	-4.5	-0.3	28.1	5.6	2.0	0.4	-0.23	-0.24	0.08	1.17	-0.00	-0.00
	15	-0.20	-0.05	9.07	0.53	-0.31	0.04	-5.8	-0.5	30.0	6.6	2.6	0.5	-0.22	-0.25	0.08	1.17	-0.00	-0.00
	20	-0.38	-0.07	10.50	0.72	-0.34	0.05	-6.9	-0.9	30.3	7.4	3.7	0.9	-0.21	-0.25	0.08	1.18	-0.00	-0.00
5	5	0.09	-0.03	4.71	0.13	-0.13	0.02	-2.6	-0.1	21.4	3.6	1.0	0.2	-0.64	-0.30	0.12	1.17	-0.00	-0.00
	10	0.06	-0.04	5.53	0.19	-0.15	0.03	-3.3	-0.2	24.0	4.2	1.5	0.2	-0.62	-0.30	0.12	1.17	-0.00	-0.00
	15	0.01	-0.05	6.31	0.26	-0.17	0.04	-4.0	-0.3	25.1	4.8	1.9	0.3	-0.61	-0.31	0.12	1.17	-0.00	-0.00
	20	-0.05	-0.06	7.04	0.33	-0.18	0.05	-4.8	-0.5	25.3	5.2	2.4	0.5	-0.62	-0.32	0.12	1.17	-0.00	-0.00
6	5	-0.27	-0.04	10.55	0.79	-0.52	0.01	-9.8	-0.3	43.9	10.9	1.8	0.4	-0.12	-0.26	0.07	1.18	-0.00	-0.00
	10	-0.88	-0.04	14.68	1.51	-0.69	0.01	-14.6	-0.8	58.3	16.1	3.1	0.8	-0.01	-0.27	0.07	1.18	-0.00	-0.00
	15	-1.84	-0.04	18.67	2.49	-0.78	0.00	-23.2	-1.7	72.7	23.3	4.8	1.6	0.00	-0.26	0.07	1.18	-0.00	-0.00
	20	-3.20	-0.04	22.85	3.77	-0.84	0.00	-34.6	-3.5	86.7	32.3	8.3	3.2	0.01	-0.26	0.07	1.18	-0.00	-0.00
7	5	-0.13	-0.04	8.56	0.65	-0.44	0.01	-5.9	-0.3	25.9	7.6	1.4	0.4	-0.63	-0.26	0.12	1.17	-0.00	-0.00
	10	-0.46	-0.05	11.11	1.09	-0.56	0.02	-8.5	-0.7	31.7	10.1	2.6	0.8	-0.58	-0.27	0.12	1.17	-0.00	-0.00
	15	-0.97	-0.06	13.69	1.68	-0.66	0.02	-11.7	-1.3	36.4	13.0	3.8	1.3	-0.56	-0.28	0.12	1.18	-0.00	-0.00
	20	-1.61	-0.09	16.06	2.35	-0.72	0.03	-15.1	-2.7	39.5	15.8	6.0	2.5	-0.56	-0.28	0.12	1.18	-0.01	-0.00
8	5	0.03	-0.02	4.13	0.21	-0.14	0.02	-3.0	-0.1	17.0	4.0	0.9	0.2	-1.08	-0.23	0.14	1.16	-0.00	-0.00
	10	-0.02	-0.03	4.88	0.29	-0.17	0.03	-3.7	-0.2	18.7	4.6	1.3	0.3	-1.07	-0.24	0.14	1.17	-0.00	-0.00
	15	-0.09	-0.05	5.52	0.37	-0.19	0.04	-4.3	-0.3	20.0	5.2	1.7	0.4	-1.05	-0.24	0.14	1.17	-0.00	-0.00
	20	-0.17	-0.06	6.19	0.47	-0.20	0.04	-4.9	-0.5	20.6	5.6	2.1	0.5	-1.05	-0.25	0.14	1.17	-0.00	-0.00
9	5	-0.57	-0.03	9.59	1.54	-0.54	-0.02	-11.8	-0.7	38.5	14.4	2.2	0.8	-5.53	-0.11	0.12	1.16	-0.01	0.00
	10	-1.39	-0.03	12.30	2.51	-0.62	-0.04	-20.6	-1.6	48.8	22.1	3.7	1.7	-5.72	-0.09	0.11	1.17	-0.01	0.00
	15	-2.95	-0.04	15.97	4.07	-0.69	-0.05	-29.1	-3.3	53.5	28.5	5.8	3.3	-5.92	-0.08	0.11	1.17	-0.01	0.00
	20	-5.15	-0.07	19.37	6.04	-0.65	-0.02	-36.9	-3.7	58.0	33.9	5.7	3.9	-6.16	-0.07	0.11	1.17	-0.01	0.00

TABLE A(III)-36 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.35	-0.03	5.71	1.11	-0.26	-0.00	-8.6	-0.4	28.5	11.9	1.4	0.6	-5.59	-0.04	0.18	1.16	-0.01	0.00
	10	-0.77	-0.04	7.52	1.70	-0.30	0.00	-13.8	-1.0	35.0	16.9	2.3	1.1	-5.71	-0.03	0.18	1.16	-0.01	0.00
	15	-1.42	-0.06	8.84	2.43	-0.29	0.01	-20.3	-2.0	40.0	22.3	3.6	2.1	-5.81	-0.01	0.18	1.17	-0.01	0.00
	20	-2.41	-0.11	10.39	3.40	-0.24	0.06	-27.8	-4.4	45.3	28.4	6.4	4.3	-5.96	-0.00	0.17	1.17	-0.01	0.00
11	5	-0.14	-0.03	3.72	0.75	-0.13	0.01	-6.2	-0.2	19.5	9.3	0.8	0.4	-3.72	-0.11	0.25	1.15	-0.01	0.00
	10	-0.30	-0.04	4.43	1.01	-0.14	0.02	-9.3	-0.4	24.1	12.5	1.2	0.6	-3.73	-0.10	0.25	1.16	-0.01	0.00
	15	-0.55	-0.06	5.21	1.34	-0.15	0.03	-13.0	-0.7	28.0	16.0	1.6	0.8	-3.71	-0.10	0.25	1.16	-0.01	0.00
	20	-0.94	-0.08	6.07	1.80	-0.14	0.05	-17.8	-1.2	32.1	20.2	2.3	1.3	-3.70	-0.10	0.25	1.17	-0.01	0.00
12	5	-0.02	-0.03	3.43	0.28	-0.13	0.02	-3.4	-0.2	14.3	4.4	0.8	0.2	-1.70	-0.16	0.20	1.16	-0.01	-0.00
	10	-0.08	-0.04	3.97	0.35	-0.15	0.03	-4.1	-0.3	16.1	5.2	1.1	0.3	-1.72	-0.16	0.20	1.16	-0.01	-0.00
	15	-0.15	-0.05	4.49	0.45	-0.16	0.04	-4.7	-0.4	17.1	5.8	1.5	0.4	-1.73	-0.17	0.20	1.16	-0.01	-0.00
	20	-0.24	-0.06	5.01	0.56	-0.17	0.05	-5.5	-0.5	17.8	6.4	1.8	0.6	-1.73	-0.17	0.20	1.16	-0.01	0.00
13	5	-0.04	-0.02	2.47	0.35	-0.06	0.02	-4.0	-0.1	13.3	5.8	0.5	0.2	-3.36	-0.08	0.29	1.14	-0.01	0.00
	10	-0.10	-0.03	2.74	0.44	-0.06	0.02	-5.2	-0.2	15.5	7.1	0.7	0.3	-3.38	-0.08	0.29	1.15	-0.01	0.00
	15	-0.18	-0.04	3.00	0.55	-0.06	0.03	-6.4	-0.3	17.4	8.4	0.9	0.3	-3.38	-0.08	0.29	1.15	-0.01	0.00
	20	-0.28	-0.05	3.27	0.68	-0.05	0.04	-7.9	-0.3	19.2	9.8	1.0	0.4	-3.37	-0.08	0.29	1.15	-0.01	0.00
14	5	-0.03	-0.02	2.39	0.36	-0.05	0.02	-4.3	-0.1	13.9	6.4	0.5	0.2	-2.78	-0.08	0.31	1.14	-0.01	0.00
	10	-0.10	-0.03	2.67	0.47	-0.05	0.03	-5.8	-0.2	16.6	8.0	0.7	0.3	-2.79	-0.08	0.31	1.15	-0.01	0.00
	15	-0.19	-0.04	2.96	0.59	-0.05	0.04	-7.4	-0.3	18.8	9.6	0.8	0.3	-2.79	-0.08	0.31	1.15	-0.01	0.00
	20	-0.30	-0.06	3.24	0.72	-0.04	0.05	-9.2	-0.3	20.9	11.3	0.9	0.4	-2.77	-0.07	0.31	1.16	-0.01	0.00
15	5	-0.01	-0.03	2.25	0.41	-0.08	0.01	-3.2	-0.2	9.2	4.9	0.6	0.3	-2.45	-0.17	0.24	1.14	-0.01	-0.00
	10	-0.03	-0.04	2.59	0.49	-0.09	0.02	-4.0	-0.4	9.9	5.7	1.0	0.5	-2.43	-0.17	0.24	1.14	-0.01	0.00
	15	-0.07	-0.05	2.87	0.57	-0.09	0.03	-4.6	-0.5	10.3	6.2	1.3	0.7	-2.40	-0.18	0.24	1.15	-0.01	0.00
	20	-0.12	-0.07	3.16	0.66	-0.09	0.05	-5.1	-0.8	10.5	6.5	1.6	0.9	-2.37	-0.18	0.24	1.15	-0.01	0.00
16	5	0.04	-0.02	3.78	0.18	-0.06	0.02	-2.9	-0.1	21.3	4.3	0.7	0.1	-1.55	-0.18	0.19	1.16	-0.00	-0.00
	10	0.01	-0.03	4.28	0.23	-0.07	0.03	-3.7	-0.1	24.0	5.1	0.8	0.2	-1.54	-0.18	0.19	1.17	-0.00	-0.00
	15	-0.05	-0.04	4.76	0.30	-0.07	0.04	-4.7	-0.2	26.0	5.8	1.0	0.2	-1.55	-0.18	0.20	1.17	-0.00	-0.00
	20	-0.11	-0.05	5.24	0.37	-0.07	0.05	-5.6	-0.2	27.0	6.4	1.3	0.2	-1.57	-0.19	0.20	1.17	-0.00	-0.00
17	5	0.04	-0.02	3.51	0.15	-0.06	0.01	-2.1	-0.1	18.2	3.1	0.7	0.1	-1.72	-0.27	0.18	1.16	-0.00	-0.00
	10	0.02	-0.03	3.99	0.19	-0.07	0.02	-2.6	-0.1	20.2	3.6	0.9	0.1	-1.68	-0.28	0.19	1.16	-0.00	-0.00
	15	-0.01	-0.04	4.40	0.23	-0.07	0.03	-3.1	-0.2	21.4	4.1	1.1	0.2	-1.69	-0.28	0.19	1.17	-0.00	-0.00
	20	-0.05	-0.05	4.81	0.28	-0.07	0.04	-3.8	-0.2	22.3	4.5	1.4	0.2	-1.70	-0.29	0.19	1.17	-0.00	-0.00
18	5	-0.05	-0.02	2.85	0.23	-0.06	0.01	-2.9	-0.1	15.1	4.3	0.5	0.1	-3.18	-0.06	0.28	1.15	-0.01	0.00
	10	-0.10	-0.02	3.10	0.30	-0.06	0.02	-3.7	-0.1	17.0	4.9	0.6	0.1	-3.18	-0.06	0.28	1.15	-0.01	0.00
	15	-0.16	-0.03	3.35	0.37	-0.06	0.03	-4.5	-0.1	18.4	5.6	0.7	0.2	-3.19	-0.06	0.28	1.16	-0.01	0.00
	20	-0.24	-0.04	3.61	0.45	-0.06	0.03	-5.3	-0.2	19.4	6.2	0.8	0.2	-3.20	-0.06	0.28	1.16	-0.01	0.00

TABLE A(III)-37. FALL PLOW SOYBEANS (D SOILS ONLY)

REGION	AW	A	B	A′	B′
1	5	0.69	18.94	-0.63	29.94
	10	0.62	18.73	-0.50	18.50
	15	0.57	18.16	-0.43	10.71
	20	0.51	17.50	-0.29	4.34
2	5	1.09	20.70	-1.05	33.40
	10	1.02	20.62	-0.93	23.26
	15	0.96	20.34	-0.82	16.26
	20	0.88	20.05	-0.73	11.47
3	5	1.50	25.10	-1.49	43.00
	10	1.54	24.76	-1.53	37.59
	15	1.54	24.52	-1.53	34.58
	20	1.53	24.22	-1.53	32.21
4	5	1.60	17.73	-1.57	41.66
	10	1.63	17.31	-1.53	32.40
	15	1.60	16.97	-1.44	26.03
	20	1.56	16.53	-1.43	21.46
5	5	1.54	20.71	-1.52	41.89
	10	1.57	20.48	-1.49	34.24
	15	1.56	20.11	-1.49	29.33
	20	1.56	19.73	-1.48	25.53
6	5	1.12	11.09	-1.03	33.05
	10	1.06	10.69	-0.81	19.49
	15	0.98	10.42	-0.65	11.46
	20	0.90	10.03	-0.47	6.16
7	5	1.60	11.01	-1.53	40.90
	10	1.64	10.53	-1.41	27.98
	15	1.61	10.01	-1.21	19.64
	20	1.57	9.55	-1.04	13.44
8	5	1.62	21.26	-1.58	43.06
	10	1.68	20.89	-1.59	35.23
	15	1.70	20.50	-1.56	30.09
	20	1.70	20.07	-1.56	26.32
9	5	1.49	8.41	-1.37	35.59
	10	1.39	7.85	-1.03	20.58
	15	1.33	7.31	-0.91	13.35
	20	1.26	6.83	-0.76	8.54
10	5	1.45	16.06	-1.38	38.67
	10	1.41	15.67	-1.14	24.67
	15	1.33	14.99	-1.01	16.52
	20	1.28	14.25	-0.81	10.40
11	5	1.31	24.19	-1.26	38.79
	10	1.25	23.93	-1.04	26.49
	15	1.23	23.32	-0.91	19.01
	20	1.20	22.65	-0.82	13.35
12	5	1.70	22.23	-1.67	44.90
	10	1.76	21.88	-1.68	36.70
	15	1.79	21.50	-1.64	31.26
	20	1.79	21.00	-1.58	26.99
13	5	1.23	35.54	-1.19	36.18
	10	1.22	35.44	-1.08	27.63
	15	1.20	35.14	-0.95	21.99
	20	1.18	34.77	-0.85	17.60
14	5	1.06	36.62	-1.02	33.41
	10	1.07	36.37	-0.90	24.68
	15	1.05	36.01	-0.80	19.14
	20	1.01	35.57	-0.70	14.88
15	5	1.78	28.55	-1.76	40.82
	10	1.82	28.19	-1.75	33.13
	15	1.84	27.73	-1.76	28.74
	20	1.84	27.27	-1.77	25.59
16	5	1.12	26.96	-1.09	38.91
	10	1.10	26.73	-1.02	31.66
	15	1.08	26.43	-0.97	26.54
	20	1.07	26.07	-0.98	23.01
17	5	1.34	25.89	-1.32	41.27
	10	1.36	25.62	-1.30	34.39
	15	1.34	25.31	-1.28	29.75
	20	1.34	24.94	-1.27	25.94
18	5	0.95	36.65	-0.94	35.50
	10	0.94	36.47	-0.90	29.08
	15	0.92	36.15	-0.86	24.64
	20	0.90	35.69	-0.85	21.22
19	5	1.13	32.19	-1.10	35.97
	10	1.13	31.97	-1.04	29.01
	15	1.10	31.68	-0.97	24.27
	20	1.08	31.27	-0.94	20.68
20	5	1.16	32.53	-1.13	36.20
	10	1.17	32.28	-1.06	27.75
	15	1.16	31.95	-0.98	22.20
	20	1.12	31.56	-0.88	17.72
21	5	1.37	32.29	-1.35	37.57
	10	1.41	31.96	-1.32	29.46
	15	1.40	31.51	-1.26	24.16
	20	1.38	31.11	-1.22	20.21
25	5	1.52	28.13	-1.50	43.08
	10	1.53	27.93	-1.48	35.77
	15	1.55	27.54	-1.50	31.00
	20	1.55	27.14	-1.49	27.37
26	5	2.23	18.57	-2.21	49.15
	10	2.30	18.08	-2.25	41.10
	15	2.34	17.50	-2.30	36.81
	20	2.36	17.07	-2.32	33.71
27	5	2.58	11.96	-2.55	50.38
	10	2.66	11.22	-2.61	41.95
	15	2.74	10.38	-2.63	36.96
	20	2.79	9.53	-2.66	33.51

TABLE A(III)-38. FALL PLOW SOYBEANS, SPRING FERTILIZATION (D SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.35	-0.03	3.53	0.67	0.07	0.02	-11.7	-0.3	42.1	11.7	0.7	0.3	-0.25	-0.09	0.39	1.18	0.02	-0.00
	10	-1.08	-0.05	5.06	1.30	0.13	0.04	-18.6	-0.6	54.1	17.1	1.3	0.5	-0.26	-0.09	0.39	1.18	0.02	-0.00
	15	-2.01	-0.08	7.08	2.06	0.22	0.06	-30.4	-1.5	76.9	26.3	3.2	1.3	-0.28	-0.09	0.38	1.18	0.02	-0.00
	20	-3.31	-0.11	9.89	3.10	0.30	0.08	-57.0	-1.4	133.4	47.8	3.5	1.6	-0.31	-0.08	0.38	1.18	0.02	-0.00
2	5	-0.09	-0.04	2.10	0.26	0.09	0.03	-7.7	-0.4	34.5	7.3	1.1	0.3	-0.23	-0.13	0.24	1.18	0.03	-0.00
	10	-0.36	-0.06	2.77	0.50	0.17	0.04	-11.6	-0.7	41.8	10.0	1.8	0.6	-0.24	-0.13	0.24	1.18	0.03	-0.00
	15	-0.76	-0.08	3.69	0.81	0.25	0.06	-16.4	-1.4	50.7	13.3	3.4	1.1	-0.24	-0.13	0.23	1.18	0.03	-0.00
	20	-1.25	-0.10	4.86	1.17	0.30	0.07	-22.0	-2.0	63.0	17.3	4.9	1.6	-0.26	-0.12	0.22	1.18	0.03	-0.00
3	5	0.03	-0.02	1.37	0.10	0.06	0.01	-3.0	-0.2	17.0	2.7	0.7	0.1	-0.26	-0.17	0.21	1.17	0.03	-0.00
	10	0.01	-0.03	1.46	0.12	0.10	0.02	-3.6	-0.2	17.8	3.1	0.9	0.2	-0.24	-0.18	0.20	1.17	0.03	-0.00
	15	-0.02	-0.04	1.56	0.15	0.14	0.03	-4.0	-0.3	18.2	3.3	1.0	0.2	-0.24	-0.18	0.20	1.17	0.03	-0.00
	20	-0.07	-0.05	1.68	0.18	0.18	0.03	-4.4	-0.3	18.7	3.5	1.0	0.2	-0.23	-0.18	0.19	1.18	0.03	-0.00
4	5	0.02	-0.04	1.69	0.27	0.07	0.02	-5.2	-0.3	20.6	5.3	0.9	0.3	-0.30	-0.21	0.25	1.17	0.04	-0.00
	10	-0.13	-0.05	1.93	0.44	0.14	0.03	-6.6	-0.6	23.3	6.4	1.5	0.5	-0.27	-0.21	0.24	1.18	0.04	-0.00
	15	-0.34	-0.07	2.33	0.64	0.20	0.05	-8.1	-1.0	26.0	7.5	2.3	0.8	-0.27	-0.22	0.23	1.18	0.04	-0.00
	20	-0.60	-0.10	2.88	0.87	0.26	0.06	-8.9	-1.7	26.8	7.8	4.1	1.5	-0.27	-0.22	0.22	1.18	0.04	-0.00
5	5	0.09	-0.03	1.12	0.16	0.07	0.02	-4.0	-0.2	17.8	4.1	0.8	0.2	-0.68	-0.26	0.21	1.17	0.04	-0.00
	10	0.04	-0.05	1.25	0.23	0.12	0.03	-5.2	-0.4	19.5	4.9	1.1	0.3	-0.67	-0.27	0.20	1.17	0.04	-0.00
	15	-0.04	-0.06	1.43	0.32	0.17	0.04	-6.1	-0.6	20.7	5.5	1.6	0.5	-0.66	-0.28	0.20	1.17	0.04	-0.00
	20	-0.14	-0.08	1.67	0.41	0.22	0.05	-6.8	-0.9	21.3	5.9	2.3	0.8	-0.67	-0.28	0.19	1.17	0.04	-0.00
6	5	-0.38	-0.04	2.02	0.93	0.13	0.01	-12.1	-0.6	36.4	12.3	1.2	0.5	-0.18	-0.22	0.13	1.18	0.05	-0.00
	10	-1.24	-0.05	3.37	1.79	0.19	0.01	-20.0	-1.4	50.6	18.8	2.8	1.3	-0.11	-0.22	0.10	1.18	0.05	-0.00
	15	-2.54	-0.07	5.80	2.96	0.26	0.02	-30.7	-3.3	71.0	27.3	6.4	2.9	-0.10	-0.21	0.10	1.18	0.05	-0.00
	20	-4.23	-0.09	9.01	4.41	0.32	0.04	-41.8	-5.3	90.8	35.5	10.6	5.0	-0.10	-0.21	0.09	1.18	0.05	-0.00
7	5	-0.17	-0.04	1.36	0.75	0.11	0.01	-7.7	-0.5	22.3	8.4	0.9	0.5	-0.61	-0.23	0.18	1.17	0.05	-0.00
	10	-0.61	-0.06	1.77	1.26	0.18	0.02	-11.0	-1.2	27.4	11.2	2.1	1.2	-0.57	-0.24	0.17	1.18	0.05	-0.00
	15	-1.24	-0.09	2.66	1.91	0.25	0.04	-14.5	-2.3	32.5	13.9	4.0	2.2	-0.55	-0.24	0.15	1.18	0.05	-0.00
	20	-2.04	-0.13	3.88	2.66	0.35	0.07	-16.7	-4.9	35.9	15.4	8.3	4.5	-0.57	-0.25	0.15	1.18	0.06	-0.00
8	5	0.02	-0.03	0.78	0.25	0.07	0.02	-4.2	-0.3	14.9	4.5	0.6	0.3	-1.04	-0.21	0.21	1.17	0.04	-0.00
	10	-0.05	-0.04	0.86	0.34	0.12	0.03	-5.2	-0.4	16.5	5.2	0.9	0.4	-1.03	-0.21	0.21	1.17	0.04	-0.00
	15	-0.15	-0.06	0.98	0.45	0.17	0.04	-6.0	-0.6	17.7	5.8	1.3	0.6	-1.03	-0.22	0.20	1.17	0.04	-0.00
	20	-0.26	-0.08	1.16	0.56	0.21	0.05	-6.7	-0.9	18.4	6.2	1.8	0.8	-1.02	-0.22	0.19	1.17	0.04	-0.00
9	5	-0.74	-0.04	0.37	1.85	0.22	-0.03	-14.9	-1.0	30.6	15.6	1.7	1.0	-5.19	-0.11	0.48	1.17	0.03	0.00
	10	-1.92	-0.04	2.05	3.10	0.24	-0.04	-24.7	-2.5	44.8	23.9	3.9	2.4	-5.30	-0.10	0.48	1.17	0.03	0.00
	15	-3.96	-0.07	5.03	5.02	0.29	-0.02	-30.9	-4.5	52.6	28.4	7.0	4.2	-5.45	-0.10	0.50	1.17	0.03	0.00
	20	-6.57	-0.16	8.86	7.31	0.42	0.05	-59.1	2.6	92.1	50.1	-2.5	-1.1	-5.69	-0.09	0.52	1.18	0.03	0.00

TABLE A(III)-38 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.44	-0.04	0.13	1.31	0.15	-0.00	-11.4	-0.7	22.3	13.2	1.0	0.8	-5.27	-0.05	0.49	1.16	0.02	0.00
	10	-1.03	-0.05	0.77	2.04	0.20	0.01	-17.7	-1.7	31.3	19.0	2.2	1.7	-5.38	-0.04	0.50	1.17	0.02	0.00
	15	-1.98	-0.09	1.96	3.01	0.26	0.03	-24.4	-3.9	39.8	24.2	5.0	3.7	-5.47	-0.03	0.51	1.17	0.02	0.00
	20	-3.32	-0.19	3.62	4.27	0.40	0.12	-31.1	-6.5	48.2	29.3	8.4	6.2	-5.59	-0.02	0.52	1.17	0.02	0.00
11	5	-0.19	-0.04	-0.00	0.90	0.10	0.01	-8.4	-0.4	16.5	10.6	0.6	0.5	-3.64	-0.09	0.38	1.16	0.02	0.00
	10	-0.43	-0.05	0.21	1.23	0.14	0.02	-12.9	-0.8	22.3	14.8	1.0	0.9	-3.65	-0.09	0.38	1.16	0.02	0.00
	15	-0.81	-0.08	0.62	1.67	0.19	0.05	-18.1	-1.6	28.7	19.3	1.6	1.6	-3.63	-0.09	0.37	1.17	0.02	0.00
	20	-1.37	-0.13	1.25	2.25	0.26	0.09	-24.1	-3.2	35.6	24.1	3.4	3.2	-3.62	-0.09	0.37	1.17	0.02	0.00
12	5	-0.04	-0.03	0.39	0.33	0.08	0.02	-4.4	-0.3	13.0	4.9	0.5	0.3	-1.70	-0.14	0.26	1.16	0.03	-0.00
	10	-0.11	-0.04	0.42	0.42	0.12	0.03	-5.4	-0.5	14.3	5.8	0.8	0.5	-1.71	-0.14	0.26	1.16	0.04	-0.00
	15	-0.21	-0.06	0.51	0.54	0.17	0.04	-6.3	-0.7	15.3	6.5	1.1	0.7	-1.72	-0.15	0.25	1.16	0.04	0.00
	20	-0.34	-0.08	0.67	0.67	0.21	0.06	-7.1	-1.0	16.4	7.1	1.4	0.9	-1.73	-0.15	0.25	1.17	0.04	0.00
13	5	-0.06	-0.03	-0.05	0.41	0.07	0.02	-5.6	-0.3	12.0	6.7	0.4	0.3	-3.30	-0.07	0.35	1.15	0.02	0.00
	10	-0.14	-0.04	0.03	0.53	0.09	0.03	-7.4	-0.4	14.9	8.5	0.5	0.5	-3.32	-0.07	0.35	1.15	0.02	0.00
	15	-0.26	-0.05	0.16	0.67	0.13	0.04	-9.4	-0.6	17.7	10.3	0.6	0.6	-3.32	-0.07	0.35	1.16	0.02	0.00
	20	-0.41	-0.08	0.35	0.83	0.16	0.06	-11.7	-0.8	20.8	12.3	0.8	0.8	-3.32	-0.07	0.35	1.16	0.02	0.00
14	5	-0.05	-0.03	-0.04	0.43	0.06	0.02	-6.2	-0.3	12.9	7.6	0.4	0.3	-2.75	-0.07	0.32	1.15	0.02	0.00
	10	-0.15	-0.04	0.05	0.56	0.09	0.03	-8.6	-0.4	16.5	9.9	0.5	0.5	-2.76	-0.07	0.32	1.15	0.02	0.00
	15	-0.28	-0.06	0.20	0.72	0.13	0.05	-11.1	-0.6	19.8	12.1	0.6	0.7	-2.75	-0.07	0.32	1.16	0.02	0.00
	20	-0.44	-0.08	0.40	0.90	0.16	0.07	-14.1	-0.9	23.4	14.7	0.8	0.9	-2.74	-0.07	0.32	1.16	0.02	0.00
15	5	-0.01	-0.03	-0.02	0.49	0.07	0.01	-4.1	-0.4	9.6	5.4	0.5	0.4	-2.45	-0.15	0.26	1.14	0.03	0.00
	10	-0.06	-0.05	-0.02	0.58	0.10	0.03	-5.0	-0.7	10.9	6.2	0.7	0.7	-2.43	-0.16	0.26	1.15	0.03	0.00
	15	-0.11	-0.07	0.01	0.69	0.13	0.04	-5.6	-1.0	11.4	6.5	1.0	1.1	-2.41	-0.16	0.26	1.15	0.03	0.00
	20	-0.18	-0.10	0.06	0.79	0.17	0.07	-5.8	-1.6	11.1	6.4	1.5	1.6	-2.38	-0.16	0.25	1.16	0.03	0.00
16	5	0.04	-0.03	1.31	0.21	0.05	0.02	-4.6	-0.2	17.3	5.1	0.5	0.2	-1.53	-0.15	0.34	1.17	0.02	-0.00
	10	-0.02	-0.04	1.45	0.28	0.09	0.03	-6.0	-0.3	19.4	6.1	0.6	0.2	-1.53	-0.15	0.34	1.17	0.02	-0.00
	15	-0.10	-0.05	1.64	0.36	0.13	0.04	-7.5	-0.3	21.5	7.1	0.7	0.3	-1.55	-0.16	0.34	1.17	0.02	-0.00
	20	-0.20	-0.07	1.86	0.45	0.16	0.05	-8.7	-0.5	22.9	7.9	1.0	0.4	-1.56	-0.16	0.33	1.17	0.02	-0.00
17	5	0.04	-0.02	0.95	0.18	0.06	0.01	-3.4	-0.2	14.9	3.7	0.5	0.2	-1.68	-0.23	0.26	1.16	0.03	-0.00
	10	0.01	-0.04	1.06	0.22	0.10	0.02	-4.3	-0.2	16.0	4.3	0.7	0.2	-1.65	-0.24	0.25	1.17	0.03	-0.00
	15	-0.04	-0.05	1.17	0.28	0.14	0.03	-5.2	-0.3	17.0	4.9	0.8	0.3	-1.67	-0.25	0.25	1.17	0.03	-0.00
	20	-0.11	-0.07	1.32	0.34	0.18	0.05	-6.0	-0.5	18.2	5.4	1.1	0.4	-1.68	-0.25	0.25	1.17	0.03	-0.00
18	5	-0.07	-0.02	0.70	0.28	0.05	0.02	-4.4	-0.2	14.7	5.1	0.3	0.2	-3.10	-0.05	0.40	1.15	0.02	0.00
	10	-0.15	-0.03	0.83	0.37	0.08	0.02	-5.6	-0.2	17.0	6.1	0.3	0.2	-3.11	-0.05	0.40	1.16	0.02	0.00
	15	-0.25	-0.04	0.98	0.46	0.11	0.03	-6.8	-0.3	18.6	6.9	0.3	0.3	-3.12	-0.05	0.40	1.16	0.02	0.00
	20	-0.37	-0.05	1.15	0.57	0.14	0.04	-8.0	-0.4	19.7	7.8	0.4	0.4	-3.13	-0.05	0.40	1.16	0.02	0.00

TABLE A(III)-38 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.06	-0.03	0.32	0.33	0.06	0.02	-5.5	-0.2	13.7	6.2	0.4	0.2	-2.28	-0.08	0.30	1.15	0.02	0.00
	10	-0.15	-0.04	0.40	0.42	0.10	0.03	-7.0	-0.4	16.1	7.5	0.4	0.3	-2.30	-0.08	0.30	1.16	0.02	0.00
	15	-0.26	-0.06	0.52	0.53	0.13	0.04	-8.5	-0.5	18.0	8.7	0.5	0.4	-2.31	-0.08	0.30	1.16	0.02	0.00
	20	-0.38	-0.07	0.66	0.64	0.16	0.06	-10.0	-0.6	19.8	9.8	0.6	0.6	-2.31	-0.08	0.30	1.16	0.02	0.00
20	5	-0.03	-0.03	0.11	0.40	0.07	0.02	-5.6	-0.3	14.1	6.7	0.3	0.3	-2.42	-0.10	0.27	1.15	0.02	-0.00
	10	-0.11	-0.04	0.16	0.51	0.11	0.03	-7.6	-0.4	16.4	8.5	0.5	0.5	-2.43	-0.09	0.27	1.16	0.02	0.00
	15	-0.23	-0.06	0.28	0.65	0.14	0.04	-9.5	-0.6	18.5	10.1	0.7	0.6	-2.43	-0.10	0.26	1.16	0.02	0.00
	20	-0.39	-0.08	0.47	0.81	0.18	0.06	-11.9	-0.8	21.5	12.1	0.9	0.8	-2.43	-0.10	0.26	1.16	0.02	0.00
21	5	-0.03	-0.03	0.09	0.43	0.07	0.02	-4.9	-0.3	12.2	6.2	0.4	0.3	-2.45	-0.10	0.27	1.15	0.02	0.00
	10	-0.10	-0.04	0.10	0.53	0.10	0.03	-6.3	-0.5	13.7	7.5	0.6	0.6	-2.46	-0.10	0.27	1.15	0.03	0.00
	15	-0.20	-0.06	0.17	0.65	0.14	0.05	-7.6	-0.8	14.9	8.6	0.9	0.9	-2.44	-0.10	0.26	1.16	0.03	0.00
	20	-0.32	-0.09	0.29	0.79	0.18	0.07	-8.9	-1.2	16.4	9.6	1.3	1.2	-2.43	-0.10	0.26	1.16	0.03	0.00
25	5	0.03	-0.03	0.61	0.29	0.06	0.02	-3.7	-0.2	11.7	4.6	0.5	0.2	-1.98	-0.13	0.32	1.15	0.03	-0.00
	10	-0.01	-0.04	0.66	0.36	0.09	0.03	-4.7	-0.3	12.7	5.4	0.6	0.3	-2.00	-0.13	0.32	1.16	0.03	0.00
	15	-0.07	-0.05	0.72	0.43	0.12	0.04	-5.6	-0.5	13.6	6.0	0.9	0.5	-2.01	-0.14	0.32	1.16	0.03	0.00
	20	-0.15	-0.07	0.82	0.52	0.16	0.05	-6.4	-0.7	14.6	6.4	1.1	0.7	-2.03	-0.14	0.32	1.16	0.03	0.00
26	5	-0.04	-0.03	0.24	0.52	0.07	0.01	-3.6	-0.3	9.0	4.7	0.6	0.4	-2.63	-0.15	0.35	1.14	0.04	0.00
	10	-0.10	-0.05	0.23	0.63	0.11	0.02	-4.3	-0.6	9.6	5.2	0.9	0.7	-2.63	-0.15	0.34	1.15	0.04	0.00
	15	-0.17	-0.07	0.25	0.74	0.15	0.04	-4.5	-1.0	10.1	5.3	1.3	1.0	-2.63	-0.15	0.34	1.15	0.04	0.00
	20	-0.26	-0.09	0.29	0.86	0.19	0.06	-4.6	-1.4	10.6	5.1	1.6	1.3	-2.65	-0.16	0.34	1.15	0.04	0.00
27	5	-0.07	-0.04	0.00	1.04	0.09	-0.02	-4.2	-0.5	7.6	5.5	0.7	0.6	-3.39	-0.29	0.34	1.14	0.04	0.00
	10	-0.17	-0.06	0.09	1.33	0.12	-0.01	-4.7	-1.0	7.6	5.7	1.3	1.2	-3.29	-0.31	0.33	1.15	0.05	0.00
	15	-0.29	-0.10	0.20	1.61	0.17	0.01	-4.6	-1.8	7.0	5.2	2.0	1.9	-3.17	-0.32	0.31	1.15	0.05	0.00
	20	-0.39	-0.15	0.28	1.81	0.22	0.05	-3.4	-3.0	5.7	3.8	3.1	2.9	-3.12	-0.34	0.31	1.16	0.05	0.00

TABLE A(III)-39. FALL PLOW SOYBEANS, FALL FERTILIZATION (D SOILS ONLY)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.29	-0.03	8.93	0.66	-0.15	0.02	-9.5	-0.2	52.8	11.3	1.3	0.3	-0.25	-0.09	0.05	1.18	-0.00	-0.00
	10	-0.90	-0.04	12.01	1.27	-0.16	0.03	-15.6	-0.5	68.2	16.5	2.2	0.5	-0.26	-0.09	0.05	1.18	-0.00	-0.00
	15	-1.69	-0.07	15.16	2.01	-0.14	0.06	-26.8	-1.4	89.4	25.7	4.3	1.3	-0.28	-0.09	0.05	1.18	-0.00	-0.00
	20	-2.84	-0.10	18.75	3.01	-0.11	0.08	-53.2	-1.4	133.1	47.1	4.7	1.6	-0.31	-0.08	0.05	1.18	0.00	-0.00
2	5	-0.07	-0.03	8.23	0.26	-0.16	0.03	-6.3	-0.3	38.5	7.0	1.6	0.3	-0.23	-0.13	0.06	1.18	-0.00	-0.00
	10	-0.29	-0.05	9.75	0.48	-0.15	0.04	-9.7	-0.6	46.4	9.6	2.8	0.6	-0.24	-0.13	0.06	1.18	-0.00	-0.00
	15	-0.61	-0.07	11.36	0.78	-0.13	0.06	-14.0	-1.3	54.9	12.9	4.4	1.1	-0.24	-0.13	0.06	1.18	-0.00	-0.00
	20	-1.02	-0.08	12.76	1.13	-0.10	0.07	-19.5	-1.9	64.3	16.9	5.6	1.6	-0.26	-0.12	0.07	1.18	0.00	-0.00
3	5	0.03	-0.02	5.00	0.10	-0.10	0.01	-2.1	-0.1	20.4	2.5	1.0	0.1	-0.26	-0.17	0.06	1.17	-0.00	-0.00
	10	0.01	-0.03	5.60	0.12	-0.11	0.02	-2.6	-0.2	21.0	2.9	1.3	0.2	-0.24	-0.18	0.06	1.17	-0.00	-0.00
	15	-0.01	-0.03	6.09	0.15	-0.11	0.03	-3.0	-0.2	20.7	3.1	1.5	0.2	-0.24	-0.18	0.06	1.17	-0.00	-0.00
	20	-0.04	-0.04	6.54	0.18	-0.10	0.03	-3.4	-0.3	20.2	3.3	1.6	0.2	-0.23	-0.18	0.06	1.18	-0.00	-0.00
4	5	0.02	-0.03	7.07	0.27	-0.22	0.02	-3.9	-0.2	25.7	5.1	1.5	0.3	-0.30	-0.21	0.08	1.17	-0.00	-0.00
	10	-0.10	-0.04	8.72	0.44	-0.26	0.03	-5.2	-0.5	28.1	6.1	2.5	0.5	-0.27	-0.21	0.08	1.18	-0.00	-0.00
	15	-0.27	-0.06	10.26	0.63	-0.29	0.05	-6.6	-0.8	29.2	7.2	3.5	0.8	-0.27	-0.22	0.08	1.18	-0.00	-0.00
	20	-0.48	-0.08	11.71	0.85	-0.30	0.06	-7.4	-1.6	27.5	7.6	5.4	1.5	-0.27	-0.22	0.08	1.18	-0.00	-0.00
5	5	0.09	-0.03	5.37	0.16	-0.12	0.02	-3.0	-0.2	22.3	3.9	1.2	0.2	-0.68	-0.26	0.12	1.17	-0.00	-0.00
	10	0.05	-0.04	6.25	0.23	-0.14	0.03	-3.9	-0.3	24.6	4.7	1.8	0.3	-0.67	-0.27	0.12	1.17	-0.00	-0.00
	15	-0.01	-0.05	7.08	0.31	-0.15	0.04	-4.7	-0.5	25.0	5.2	2.5	0.5	-0.66	-0.28	0.12	1.17	-0.00	-0.00
	20	-0.09	-0.06	7.86	0.40	-0.16	0.05	-5.4	-0.8	24.2	5.6	3.3	0.7	-0.67	-0.28	0.12	1.17	-0.00	-0.00
6	5	-0.33	-0.03	12.21	0.93	-0.50	0.01	-10.0	-0.5	45.7	11.9	2.1	0.5	-0.18	-0.22	0.07	1.18	-0.00	-0.00
	10	-1.07	-0.04	16.67	1.76	-0.63	0.01	-17.3	-1.3	60.6	18.3	4.3	1.3	-0.11	-0.22	0.07	1.18	-0.00	-0.00
	15	-2.22	-0.06	21.00	2.90	-0.68	0.02	-27.9	-3.1	74.0	26.8	7.9	2.9	-0.10	-0.21	0.06	1.18	-0.00	-0.00
	20	-3.77	-0.08	25.34	4.32	-0.69	0.04	-38.5	-5.3	84.0	34.9	11.2	4.9	-0.10	-0.21	0.06	1.18	-0.00	-0.00
7	5	-0.16	-0.04	9.68	0.75	-0.43	0.01	-6.5	-0.4	26.5	8.2	1.6	0.5	-0.61	-0.23	0.11	1.17	-0.00	-0.00
	10	-0.54	-0.05	12.34	1.25	-0.53	0.02	-9.5	-1.0	31.4	10.9	3.2	1.1	-0.57	-0.24	0.11	1.18	-0.00	-0.00
	15	-1.11	-0.07	14.94	1.88	-0.59	0.03	-12.9	-2.2	34.2	13.6	5.2	2.2	-0.55	-0.24	0.11	1.18	-0.00	-0.00
	20	-1.84	-0.11	17.44	2.62	-0.61	0.06	-15.1	-4.7	34.7	15.1	8.7	4.5	-0.57	-0.25	0.12	1.18	-0.00	-0.00
8	5	0.02	-0.02	4.78	0.25	-0.14	0.02	-3.4	-0.2	17.4	4.3	1.1	0.2	-1.04	-0.21	0.13	1.17	-0.00	-0.00
	10	-0.04	-0.04	5.59	0.34	-0.17	0.03	-4.2	-0.3	19.1	5.1	1.7	0.4	-1.03	-0.21	0.13	1.17	-0.00	-0.00
	15	-0.12	-0.05	6.30	0.44	-0.17	0.04	-5.0	-0.5	20.1	5.6	2.2	0.6	-1.03	-0.22	0.13	1.17	-0.00	-0.00
	20	-0.21	-0.06	7.02	0.55	-0.18	0.05	-5.6	-0.8	19.8	6.0	2.9	0.8	-1.02	-0.22	0.13	1.17	-0.00	-0.00
9	5	-0.69	-0.03	11.78	1.84	-0.58	-0.03	-13.0	-0.9	38.7	15.3	2.5	1.0	-5.19	-0.11	0.12	1.17	-0.01	0.00
	10	-1.76	-0.04	15.29	3.07	-0.66	-0.04	-22.9	-2.4	48.1	23.6	4.7	2.4	-5.30	-0.10	0.11	1.17	-0.01	0.00
	15	-3.73	-0.06	19.53	4.98	-0.69	-0.02	-29.4	-4.3	49.7	28.1	6.6	4.2	-5.45	-0.10	0.11	1.17	-0.01	0.00
	20	-6.29	-0.15	23.25	7.26	-0.58	0.05	-56.9	2.6	79.8	49.7	-2.8	-1.1	-5.69	-0.09	0.11	1.18	-0.01	0.00

TABLE A(III)-39 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.41	-0.03	6.81	1.31	-0.26	-0.00	-9.8	-0.6	29.3	12.9	1.7	0.7	-5.27	-0.05	0.18	1.16	-0.01	0.00
	10	-0.95	-0.05	8.93	2.03	-0.29	0.01	-16.1	-1.5	35.3	18.7	3.1	1.7	-5.38	-0.04	0.18	1.17	-0.01	0.00
	15	-1.83	-0.08	10.78	2.99	-0.27	0.03	-22.9	-3.7	39.0	24.0	5.7	3.7	-5.47	-0.03	0.17	1.17	-0.01	0.00
	20	-3.13	-0.17	12.76	4.23	-0.17	0.11	-29.7	-6.3	42.6	29.0	8.3	6.2	-5.59	-0.02	0.17	1.17	-0.01	0.00
11	5	-0.18	-0.03	4.39	0.89	-0.13	0.01	-7.3	-0.4	20.4	10.4	1.0	0.5	-3.64	-0.09	0.24	1.16	-0.01	0.00
	10	-0.40	-0.04	5.27	1.22	-0.13	0.02	-11.6	-0.7	25.3	14.5	1.7	0.9	-3.65	-0.09	0.24	1.16	-0.01	0.00
	15	-0.75	-0.07	6.23	1.66	-0.13	0.05	-16.8	-1.5	29.3	19.0	2.7	1.6	-3.63	-0.09	0.24	1.17	-0.01	0.00
	20	-1.27	-0.12	7.21	2.23	-0.10	0.08	-22.7	-3.1	32.6	23.9	4.7	3.2	-3.62	-0.09	0.24	1.17	-0.01	0.00
12	5	-0.04	-0.03	4.06	0.33	-0.13	0.02	-3.8	-0.2	14.9	4.8	0.9	0.3	-1.70	-0.14	0.19	1.16	-0.01	-0.00
	10	-0.10	-0.04	4.67	0.42	-0.15	0.03	-4.6	-0.4	16.4	5.6	1.4	0.5	-1.71	-0.14	0.20	1.16	-0.01	-0.00
	15	-0.19	-0.05	5.26	0.53	-0.15	0.04	-5.4	-0.6	16.9	6.3	1.9	0.7	-1.72	-0.15	0.20	1.16	-0.01	0.00
	20	-0.30	-0.07	5.85	0.66	-0.16	0.05	-6.2	-0.9	16.9	6.9	2.5	0.9	-1.73	-0.15	0.20	1.17	-0.01	0.00
13	5	-0.06	-0.02	2.91	0.41	-0.06	0.02	-4.8	-0.2	13.9	6.6	0.7	0.3	-3.30	-0.07	0.28	1.15	-0.01	0.00
	10	-0.13	-0.03	3.22	0.53	-0.06	0.03	-6.5	-0.4	16.3	8.3	1.1	0.5	-3.32	-0.07	0.28	1.15	-0.01	0.00
	15	-0.24	-0.05	3.54	0.66	-0.05	0.04	-8.4	-0.5	18.3	10.1	1.4	0.6	-3.32	-0.07	0.29	1.16	-0.01	0.00
	20	-0.37	-0.07	3.88	0.82	-0.04	0.06	-10.6	-0.7	20.2	12.1	1.7	0.8	-3.32	-0.07	0.29	1.16	-0.01	0.00
14	5	-0.05	-0.02	2.82	0.43	-0.05	0.02	-5.4	-0.2	14.7	7.4	0.7	0.3	-2.75	-0.07	0.30	1.15	-0.01	0.00
	10	-0.14	-0.03	3.17	0.56	-0.05	0.03	-7.6	-0.4	17.8	9.7	1.0	0.5	-2.76	-0.07	0.30	1.15	-0.01	0.00
	15	-0.26	-0.05	3.52	0.72	-0.04	0.04	-10.0	-0.6	20.3	11.9	1.4	0.7	-2.75	-0.07	0.30	1.16	-0.01	0.00
	20	-0.40	-0.07	3.86	0.89	-0.02	0.06	-12.9	-0.8	22.8	14.4	1.7	0.9	-2.74	-0.07	0.30	1.16	-0.01	0.00
15	5	-0.02	-0.03	2.71	0.49	-0.08	0.01	-3.7	-0.3	9.1	5.3	0.8	0.4	-2.45	-0.15	0.24	1.14	-0.01	0.00
	10	-0.06	-0.04	3.13	0.58	-0.09	0.03	-4.7	-0.6	9.8	6.1	1.3	0.7	-2.43	-0.16	0.24	1.15	-0.01	0.00
	15	-0.11	-0.06	3.47	0.68	-0.09	0.04	-5.2	-0.9	10.0	6.4	1.7	1.1	-2.41	-0.16	0.24	1.15	-0.01	0.00
	20	-0.17	-0.09	3.80	0.79	-0.07	0.07	-5.3	-1.5	9.0	6.3	2.2	1.6	-2.38	-0.16	0.24	1.16	-0.01	0.00
16	5	0.04	-0.02	4.29	0.21	-0.06	0.02	-3.4	-0.1	22.8	4.8	0.8	0.2	-1.53	-0.15	0.18	1.17	-0.00	-0.00
	10	-0.00	-0.03	4.84	0.28	-0.06	0.03	-4.6	-0.2	25.7	5.8	1.1	0.2	-1.53	-0.15	0.19	1.17	-0.00	-0.00
	15	-0.07	-0.04	5.37	0.35	-0.05	0.04	-5.9	-0.3	27.7	6.8	1.4	0.3	-1.55	-0.16	0.19	1.17	-0.00	-0.00
	20	-0.15	-0.06	5.90	0.44	-0.05	0.05	-7.2	-0.4	28.3	7.6	1.8	0.4	-1.56	-0.16	0.19	1.17	-0.00	-0.00
17	5	0.04	-0.02	3.96	0.18	-0.05	0.01	-2.4	-0.1	19.4	3.5	0.8	0.2	-1.68	-0.23	0.17	1.16	-0.00	-0.00
	10	0.02	-0.03	4.45	0.22	-0.05	0.02	-3.1	-0.2	21.2	4.1	1.2	0.2	-1.65	-0.24	0.18	1.17	-0.00	-0.00
	15	-0.02	-0.04	4.88	0.27	-0.05	0.03	-3.9	-0.3	22.4	4.7	1.5	0.3	-1.67	-0.25	0.18	1.17	-0.00	-0.00
	20	-0.07	-0.05	5.33	0.33	-0.05	0.04	-4.7	-0.4	22.9	5.2	1.9	0.4	-1.68	-0.25	0.18	1.17	-0.00	-0.00
18	5	-0.06	-0.02	3.29	0.28	-0.06	0.01	-3.7	-0.1	16.4	5.0	0.6	0.2	-3.10	-0.05	0.26	1.15	-0.01	0.00
	10	-0.14	-0.02	3.60	0.37	-0.05	0.02	-4.8	-0.2	18.4	5.9	0.8	0.2	-3.11	-0.05	0.27	1.16	-0.01	0.00
	15	-0.22	-0.03	3.89	0.46	-0.05	0.03	-5.9	-0.2	19.8	6.8	1.0	0.3	-3.12	-0.05	0.27	1.16	-0.01	0.00
	20	-0.32	-0.04	4.21	0.56	-0.04	0.04	-7.0	-0.3	20.6	7.6	1.3	0.3	-3.13	-0.05	0.27	1.16	-0.01	0.00

TABLE A(III)-39 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.06	-0.02	2.98	0.33	-0.03	0.02	-4.7	-0.2	16.3	6.1	0.7	0.2	-2.28	-0.08	0.28	1.15	-0.00	0.00
	10	-0.14	-0.04	3.30	0.42	-0.03	0.03	-6.1	-0.3	18.5	7.3	0.9	0.3	-2.30	-0.08	0.28	1.16	-0.00	0.00
	15	-0.23	-0.05	3.57	0.52	-0.02	0.04	-7.5	-0.4	20.2	8.5	1.1	0.4	-2.31	-0.08	0.28	1.16	-0.00	0.00
	20	-0.33	-0.06	3.87	0.63	-0.01	0.06	-8.9	-0.6	21.3	9.7	1.4	0.6	-2.31	-0.08	0.28	1.16	-0.00	0.00
20	5	-0.03	-0.02	3.12	0.40	-0.06	0.02	-4.9	-0.2	15.5	6.6	0.7	0.3	-2.42	-0.10	0.26	1.15	-0.01	-0.00
	10	-0.10	-0.04	3.55	0.51	-0.06	0.03	-6.6	-0.4	18.4	8.3	1.1	0.5	-2.43	-0.09	0.26	1.16	-0.01	0.00
	15	-0.21	-0.05	3.94	0.64	-0.06	0.04	-8.3	-0.6	20.3	9.9	1.5	0.6	-2.43	-0.10	0.26	1.16	-0.01	0.00
	20	-0.35	-0.07	4.33	0.80	-0.04	0.06	-10.6	-0.8	22.2	11.9	1.8	0.8	-2.43	-0.10	0.26	1.16	-0.01	0.00
21	5	-0.03	-0.02	2.81	0.43	-0.06	0.02	-4.4	-0.2	12.9	6.1	0.7	0.3	-2.45	-0.10	0.25	1.15	-0.01	0.00
	10	-0.09	-0.04	3.20	0.53	-0.06	0.03	-5.6	-0.5	14.5	7.4	1.2	0.6	-2.46	-0.10	0.25	1.15	-0.01	0.00
	15	-0.18	-0.06	3.54	0.65	-0.06	0.04	-6.8	-0.8	15.2	8.4	1.6	0.8	-2.44	-0.10	0.25	1.16	-0.01	0.00
	20	-0.30	-0.08	3.90	0.79	-0.04	0.06	-8.0	-1.2	15.2	9.4	2.2	1.2	-2.43	-0.10	0.25	1.16	-0.01	0.00
25	5	0.03	-0.02	3.51	0.29	-0.09	0.02	-3.0	-0.2	14.2	4.5	0.8	0.2	-1.98	-0.13	0.23	1.15	-0.01	-0.00
	10	-0.01	-0.03	3.93	0.36	-0.09	0.03	-3.9	-0.3	15.4	5.2	1.1	0.3	-2.00	-0.13	0.23	1.16	-0.01	0.00
	15	-0.06	-0.05	4.33	0.43	-0.10	0.04	-4.7	-0.4	15.8	5.8	1.6	0.5	-2.01	-0.14	0.23	1.16	-0.01	0.00
	20	-0.13	-0.06	4.71	0.51	-0.09	0.05	-5.5	-0.6	15.6	6.3	2.0	0.7	-2.03	-0.14	0.23	1.16	-0.01	0.00
26	5	-0.04	-0.03	3.57	0.52	-0.16	0.01	-3.1	-0.3	9.7	4.6	0.9	0.4	-2.63	-0.15	0.11	1.14	-0.01	0.00
	10	-0.10	-0.04	4.00	0.63	-0.17	0.02	-3.8	-0.6	9.7	5.1	1.4	0.7	-2.63	-0.15	0.11	1.15	-0.01	0.00
	15	-0.17	-0.06	4.40	0.74	-0.17	0.03	-4.2	-0.9	9.0	5.2	1.9	1.0	-2.63	-0.15	0.11	1.15	-0.01	0.00
	20	-0.24	-0.08	4.77	0.86	-0.16	0.05	-4.3	-1.3	8.1	5.1	2.3	1.3	-2.65	-0.16	0.12	1.15	-0.01	0.00
27	5	-0.07	-0.03	4.27	1.04	-0.23	-0.02	-3.6	-0.4	9.5	5.4	1.2	0.6	-3.39	-0.29	0.14	1.14	-0.01	0.00
	10	-0.16	-0.05	5.33	1.33	-0.27	-0.01	-4.2	-1.0	8.5	5.6	1.8	1.2	-3.29	-0.31	0.14	1.15	-0.01	0.00
	15	-0.27	-0.09	6.27	1.60	-0.29	0.01	-4.2	-1.7	6.6	5.1	2.4	1.9	-3.17	-0.32	0.14	1.15	-0.01	0.00
	20	-0.36	-0.14	6.80	1.80	-0.28	0.05	-3.1	-2.9	4.3	3.7	3.3	2.9	-3.12	-0.34	0.14	1.16	-0.01	0.00

TABLE A(III)-40. SPRING PLOW SOYBEANS (A AND B SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.79	-3.43	-1.73	52.21	10	5	2.55	-3.82	-2.49	61.49	19	5	3.88	-6.76	-3.85	75.59
	10	1.70	-3.34	-1.58	40.39		10	2.46	-3.71	-2.29	48.08		10	3.89	-6.92	-3.81	68.69
	15	1.62	-3.26	-1.47	31.53		15	2.36	-3.62	-2.18	38.24		15	3.85	-6.94	-3.74	63.58
	20	1.53	-3.08	-1.37	23.77		20	2.28	-3.54	-2.06	30.20		20	3.81	-7.00	-3.70	59.35
2	5	2.68	-4.77	-2.65	58.77	11	5	3.14	-5.05	-3.10	69.97	20	5	3.92	-6.18	-3.91	77.13
	10	2.61	-4.65	-2.51	48.44		10	3.06	-5.00	-2.96	58.71		10	3.91	-6.29	-3.87	69.69
	15	2.53	-4.59	-2.40	40.86		15	3.03	-5.06	-2.86	50.42		15	3.89	-6.38	-3.83	64.00
	20	2.45	-4.41	-2.31	35.15		20	2.96	-5.07	-2.76	43.45		20	3.85	-6.44	-3.76	59.08
3	5	3.45	-5.06	-3.45	73.14	12	5	3.37	-4.88	-3.35	73.41	21	5	4.14	-5.72	-4.13	78.46
	10	3.49	-5.31	-3.48	67.62		10	3.40	-5.05	-3.34	65.63		10	4.15	-5.84	-4.11	71.28
	15	3.48	-5.37	-3.48	64.40		15	3.42	-5.17	-3.32	60.00		15	4.13	-5.94	-4.07	65.89
	20	3.47	-5.47	-3.47	61.72		20	3.40	-5.32	-3.28	55.26		20	4.09	-6.01	-4.04	61.30
4	5	2.91	-5.01	-2.88	64.38	13	5	4.18	-5.47	-4.16	78.78	25	5	3.80	-6.71	-3.78	76.90
	10	2.94	-5.26	-2.84	54.93		10	4.15	-5.49	-4.06	70.98		10	3.85	-6.85	-3.80	69.36
	15	2.90	-5.32	-2.74	48.21		15	4.14	-5.65	-4.00	65.23		15	3.87	-6.96	-3.80	64.27
	20	2.86	-5.37	-2.74	43.08		20	4.13	-5.77	-3.91	60.12		20	3.86	-7.01	-3.76	60.10
5	5	3.23	-5.52	-3.21	68.10	14	5	4.24	-6.01	-4.22	78.40	26	5	3.77	-5.48	-3.76	73.58
	10	3.25	-5.66	-3.18	60.35		10	4.22	-6.10	-4.15	71.02		10	3.82	-5.73	-3.80	66.32
	15	3.24	-5.77	-3.17	55.12		15	4.18	-6.16	-4.08	65.26		15	3.85	-5.95	-3.84	62.02
	20	3.23	-5.80	-3.15	50.73		20	4.14	-6.28	-4.02	60.48		20	3.86	-6.00	-3.84	58.48
6	5	1.80	-3.55	-1.70	47.65	15	5	4.21	-4.98	-4.21	76.86	27	5	3.52	-4.45	-3.51	69.43
	10	1.73	-3.61	-1.48	33.54		10	4.23	-5.28	-4.21	70.17		10	3.55	-4.71	-3.54	61.77
	15	1.63	-3.45	-1.27	24.71		15	4.23	-5.47	-4.20	65.44		15	3.58	-5.01	-3.58	56.68
	20	1.54	-3.29	-1.17	18.17		20	4.21	-5.54	-4.20	61.54		20	3.58	-5.14	-3.57	52.60
7	5	2.38	-4.58	-2.32	56.43	16	5	3.14	-4.79	-3.11	70.65						
	10	2.43	-4.85	-2.20	43.28		10	3.12	-4.95	-3.04	63.32						
	15	2.38	-4.92	-1.98	34.42		15	3.09	-4.96	-2.98	57.88						
	20	2.32	-4.86	-1.81	27.39		20	3.08	-5.05	-2.99	53.92						
8	5	3.31	-5.54	-3.27	69.84	17	5	3.42	-6.04	-3.41	73.15						
	10	3.38	-5.81	-3.28	61.90		10	3.44	-6.26	-3.39	66.21						
	15	3.39	-5.98	-3.25	56.47		15	3.42	-6.33	-3.36	61.26						
	20	3.38	-6.14	-3.24	52.33		20	3.41	-6.38	-3.34	56.94						
9	5	1.94	-2.92	-1.85	50.50	18	5	3.99	-6.82	-3.99	78.90						
	10	1.79	-2.73	-1.59	35.19		10	3.98	-6.93	-3.94	72.40						
	15	1.72	-2.74	-1.44	25.25		15	3.93	-6.93	-3.88	67.59						
	20	1.64	-2.73	-1.26	17.94		20	3.90	-6.98	-3.85	63.55						

TABLE A(III)-41. SPRING PLOW SOYBEANS, SPRING FERTILIZATION (A ANB B SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.05	-0.06	5.84	0.31	-0.31	0.05	-6.2	-0.4	26.3	6.8	1.1	0.3	-0.31	-0.15	1.05	1.16	-0.05	0.00
	10	0.06	-0.14	6.03	0.25	-0.18	0.11	-8.3	-0.6	29.2	8.5	1.5	0.5	-0.26	-0.15	1.03	1.16	-0.05	0.00
	15	0.12	-0.23	5.82	0.21	0.04	0.18	-10.9	-1.0	32.9	10.4	2.4	0.8	-0.32	-0.15	1.02	1.17	-0.05	0.00
	20	0.12	-0.33	6.09	0.24	0.26	0.27	-14.4	-1.8	38.6	13.0	4.2	1.5	-0.36	-0.14	1.02	1.17	-0.05	0.00
2	5	-0.04	-0.04	2.48	0.14	-0.06	0.03	-3.9	-0.4	19.9	4.0	1.5	0.4	-0.13	-0.18	0.49	1.17	0.00	0.00
	10	-0.04	-0.08	2.70	0.17	0.03	0.06	-4.9	-0.6	21.2	4.7	2.0	0.5	-0.05	-0.19	0.45	1.17	0.01	0.00
	15	-0.10	-0.12	2.75	0.22	0.15	0.09	-6.0	-1.0	21.6	5.3	2.8	0.8	0.10	-0.20	0.39	1.17	0.01	0.00
	20	-0.21	-0.16	3.07	0.31	0.25	0.12	-6.7	-1.4	21.5	5.6	4.0	1.1	0.06	-0.20	0.38	1.17	0.01	0.00
3	5	-0.04	-0.01	1.63	0.08	-0.05	0.01	-1.5	-0.2	10.6	1.5	0.9	0.1	-0.64	-0.18	0.47	1.15	0.01	0.00
	10	-0.02	-0.03	1.64	0.07	-0.01	0.02	-1.7	-0.2	10.5	1.6	1.1	0.2	-0.55	-0.20	0.43	1.15	0.01	0.00
	15	-0.01	-0.04	1.61	0.06	0.03	0.03	-1.8	-0.3	10.3	1.7	1.2	0.2	-0.55	-0.20	0.41	1.16	0.01	0.00
	20	0.00	-0.05	1.52	0.06	0.08	0.04	-2.0	-0.3	10.2	1.7	1.2	0.2	-0.51	-0.21	0.38	1.16	0.02	0.00
4	5	-0.11	-0.02	3.09	0.21	-0.14	0.02	-3.0	-0.3	14.2	3.4	1.0	0.3	-1.31	-0.18	0.93	1.15	-0.02	0.00
	10	-0.08	-0.05	3.28	0.20	-0.09	0.05	-3.5	-0.5	14.9	3.8	1.4	0.4	-1.13	-0.20	0.90	1.15	-0.02	0.00
	15	-0.04	-0.09	3.34	0.19	-0.02	0.07	-4.1	-0.6	15.3	4.2	1.8	0.6	-1.12	-0.20	0.88	1.15	-0.02	0.00
	20	-0.02	-0.12	3.43	0.19	0.06	0.10	-4.4	-0.9	15.3	4.4	2.4	0.8	-1.08	-0.21	0.86	1.16	-0.02	0.00
5	5	-0.04	-0.02	1.75	0.11	-0.05	0.02	-2.1	-0.2	11.3	2.4	1.0	0.2	-1.37	-0.28	0.55	1.15	0.01	0.00
	10	-0.01	-0.04	1.84	0.11	-0.00	0.03	-2.4	-0.3	11.4	2.7	1.2	0.3	-1.25	-0.29	0.52	1.15	0.01	0.00
	15	0.01	-0.06	1.70	0.10	0.06	0.05	-2.7	-0.5	11.3	2.8	1.5	0.4	-1.22	-0.30	0.49	1.16	0.01	0.00
	20	0.02	-0.08	1.65	0.10	0.13	0.07	-2.9	-0.6	11.1	2.9	1.8	0.5	-1.32	-0.30	0.48	1.16	0.02	0.00
6	5	-0.18	-0.06	3.81	0.33	-0.09	0.05	-8.0	-0.5	26.2	8.7	1.2	0.5	-1.68	-0.17	0.74	1.16	0.00	0.00
	10	-0.01	-0.14	4.14	0.29	0.03	0.12	-11.5	-1.0	31.7	11.7	2.1	0.9	-0.68	-0.26	0.60	1.17	0.02	0.00
	15	0.04	-0.24	3.88	0.32	0.27	0.20	-15.3	-1.7	38.2	14.9	3.6	1.6	-0.45	-0.28	0.52	1.17	0.02	0.00
	20	-0.02	-0.36	4.35	0.42	0.48	0.29	-19.3	-3.3	45.3	18.0	6.5	2.9	-0.08	-0.31	0.50	1.17	0.02	0.00
7	5	-0.22	-0.04	2.77	0.35	-0.07	0.04	-5.2	-0.4	16.5	6.2	0.9	0.4	-2.23	-0.15	0.86	1.15	-0.00	0.00
	10	-0.21	-0.08	3.07	0.39	0.00	0.08	-6.8	-0.8	18.8	7.6	1.6	0.8	-1.92	-0.19	0.83	1.16	0.00	0.00
	15	-0.25	-0.14	3.21	0.48	0.11	0.12	-8.4	-1.3	21.0	9.1	2.4	1.2	-1.75	-0.21	0.77	1.16	0.01	0.00
	20	-0.33	-0.21	3.42	0.60	0.24	0.18	-9.8	-2.2	22.8	10.2	3.8	2.0	-1.72	-0.21	0.76	1.16	0.01	0.00
8	5	-0.13	-0.02	1.71	0.19	-0.06	0.02	-2.2	-0.2	9.2	2.7	0.8	0.3	-3.34	-0.05	0.84	1.13	-0.02	0.00
	10	-0.13	-0.03	1.80	0.21	-0.02	0.03	-2.5	-0.4	9.4	2.9	1.0	0.4	-3.32	-0.06	0.82	1.13	-0.01	0.00
	15	-0.13	-0.05	1.76	0.21	0.03	0.05	-2.7	-0.5	9.6	3.1	1.2	0.5	-3.35	-0.06	0.82	1.13	-0.01	0.00
	20	-0.14	-0.07	1.69	0.23	0.09	0.06	-2.9	-0.6	9.6	3.2	1.4	0.6	-3.55	-0.04	0.80	1.14	-0.01	0.00
9	5	-0.03	-0.07	5.39	0.46	-0.24	0.07	-8.5	-0.6	28.7	11.4	1.3	0.7	-2.65	-0.20	1.22	1.15	-0.04	0.00
	10	0.02	-0.15	6.03	0.54	-0.18	0.13	-13.7	-1.3	32.3	15.8	2.3	1.3	-2.62	-0.22	1.24	1.16	-0.04	0.00
	15	-0.03	-0.28	5.93	0.61	0.03	0.25	-19.2	-2.7	37.0	20.0	4.5	2.5	-3.04	-0.22	1.24	1.16	-0.04	0.00
	20	-0.19	-0.48	6.32	0.83	0.30	0.42	-27.2	-4.0	46.1	26.3	6.6	3.8	-3.17	-0.23	1.24	1.16	-0.04	0.00

TABLE A(III)-41 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.09	-0.04	3.72	0.42	-0.18	0.05	-5.5	-0.5	18.7	8.5	1.1	0.6	-4.26	-0.02	1.15	1.13	-0.04	0.00
	10	-0.12	-0.09	3.81	0.48	-0.11	0.10	-7.6	-0.9	19.8	10.5	1.5	1.0	-4.56	0.00	1.16	1.14	-0.04	0.00
	15	-0.06	-0.17	3.81	0.47	0.00	0.18	-9.7	-1.8	20.9	12.2	2.5	1.7	-4.58	-0.01	1.15	1.15	-0.04	0.00
	20	-0.06	-0.30	3.75	0.49	0.18	0.29	-11.2	-3.5	21.3	13.2	4.6	3.3	-4.91	0.01	1.15	1.15	-0.04	0.00
11	5	-0.08	-0.03	2.93	0.43	-0.17	0.03	-3.4	-0.4	11.6	5.9	0.8	0.5	-2.94	-0.07	1.01	1.12	-0.04	0.00
	10	-0.07	-0.06	3.09	0.46	-0.14	0.06	-4.3	-0.7	11.7	6.8	1.0	0.7	-2.88	-0.07	0.99	1.13	-0.04	0.00
	15	-0.04	-0.10	3.27	0.50	-0.10	0.10	-5.2	-1.0	11.7	7.5	1.4	1.1	-2.94	-0.08	0.99	1.13	-0.04	0.00
	20	-0.05	-0.16	3.23	0.52	-0.02	0.15	-5.9	-1.6	11.7	8.1	1.9	1.6	-3.19	-0.06	1.00	1.14	-0.04	0.00
12	5	-0.08	-0.02	2.11	0.23	-0.11	0.02	-2.1	-0.2	8.3	3.0	0.7	0.3	-2.13	-0.11	0.95	1.11	-0.03	0.00
	10	-0.07	-0.04	2.19	0.24	-0.09	0.03	-2.4	-0.3	8.8	3.2	0.8	0.4	-2.24	-0.11	0.94	1.12	-0.03	0.00
	15	-0.07	-0.06	2.28	0.25	-0.06	0.05	-2.7	-0.5	8.9	3.4	0.9	0.5	-2.29	-0.11	0.94	1.12	-0.03	0.00
	20	-0.05	-0.08	2.32	0.24	-0.02	0.07	-3.0	-0.6	8.8	3.6	1.1	0.6	-2.30	-0.12	0.94	1.13	-0.03	0.00
13	5	-0.08	-0.02	1.33	0.25	-0.06	0.02	-1.7	-0.3	6.0	2.9	0.7	0.4	-4.06	0.05	0.80	1.09	-0.03	0.00
	10	-0.09	-0.03	1.35	0.28	-0.04	0.03	-1.9	-0.4	6.3	3.1	0.8	0.5	-4.19	0.06	0.80	1.10	-0.02	0.00
	15	-0.08	-0.05	1.37	0.28	-0.01	0.05	-2.1	-0.6	6.2	3.2	0.8	0.6	-4.25	0.07	0.79	1.10	-0.02	0.00
	20	-0.10	-0.07	1.37	0.30	0.03	0.07	-2.3	-0.7	6.0	3.4	1.0	0.7	-4.41	0.07	0.79	1.11	-0.02	0.00
14	5	-0.07	-0.02	0.97	0.24	-0.03	0.02	-1.7	-0.3	6.0	3.0	0.8	0.4	-3.76	0.07	0.73	1.09	-0.02	0.01
	10	-0.09	-0.03	1.03	0.26	-0.01	0.04	-1.9	-0.5	6.2	3.2	0.8	0.5	-3.84	0.08	0.73	1.09	-0.02	0.01
	15	-0.09	-0.05	1.03	0.28	0.03	0.06	-2.1	-0.6	6.2	3.3	0.9	0.7	-3.88	0.08	0.71	1.10	-0.02	0.01
	20	-0.10	-0.07	0.99	0.29	0.07	0.08	-2.2	-0.8	6.0	3.4	1.0	0.8	-3.94	0.09	0.69	1.11	-0.02	0.00
15	5	-0.07	-0.02	1.00	0.24	-0.03	0.03	-1.4	-0.3	5.4	2.8	0.7	0.4	-3.15	-0.03	0.70	1.08	-0.01	0.01
	10	-0.06	-0.03	1.03	0.25	-0.02	0.04	-1.5	-0.4	5.6	2.9	0.7	0.5	-3.21	-0.02	0.69	1.09	-0.01	0.01
	15	-0.05	-0.05	1.04	0.26	0.00	0.05	-1.6	-0.5	5.5	2.9	0.8	0.6	-3.15	-0.03	0.67	1.09	-0.01	0.01
	20	-0.04	-0.07	1.05	0.26	0.03	0.07	-1.5	-0.7	5.3	2.9	0.9	0.8	-3.21	-0.03	0.67	1.10	-0.01	0.01
16	5	-0.07	-0.02	2.90	0.19	-0.17	0.02	-2.1	-0.2	10.1	2.7	0.8	0.2	-1.42	-0.23	0.79	1.14	-0.02	0.00
	10	-0.03	-0.04	2.95	0.18	-0.13	0.03	-2.5	-0.3	10.1	3.0	0.9	0.3	-1.27	-0.25	0.76	1.14	-0.01	0.00
	15	-0.02	-0.06	3.01	0.19	-0.09	0.05	-2.8	-0.4	10.3	3.2	1.0	0.3	-1.29	-0.25	0.75	1.14	-0.01	0.00
	20	-0.02	-0.08	2.93	0.19	-0.03	0.06	-3.1	-0.4	10.3	3.3	1.2	0.4	-1.39	-0.25	0.72	1.15	-0.01	0.00
17	5	-0.09	-0.01	1.69	0.16	-0.07	0.01	-1.6	-0.2	8.9	2.0	0.7	0.2	-3.62	-0.13	0.69	1.13	-0.01	0.00
	10	-0.08	-0.03	1.85	0.17	-0.04	0.02	-1.8	-0.2	8.9	2.2	0.9	0.2	-3.35	-0.17	0.64	1.14	-0.00	0.00
	15	-0.08	-0.04	1.66	0.17	0.02	0.03	-2.0	-0.3	8.8	2.3	1.0	0.3	-3.57	-0.15	0.62	1.14	-0.00	0.00
	20	-0.09	-0.06	1.63	0.18	0.07	0.05	-2.2	-0.4	8.7	2.4	1.1	0.4	-3.75	-0.14	0.61	1.14	-0.00	0.00
18	5	-0.09	-0.01	1.30	0.19	-0.05	0.01	-1.6	-0.2	6.3	2.2	0.7	0.3	-4.19	0.01	0.78	1.10	-0.02	0.00
	10	-0.09	-0.03	1.42	0.21	-0.03	0.02	-1.8	-0.3	6.5	2.3	0.8	0.3	-4.12	0.01	0.75	1.11	-0.02	0.00
	15	-0.11	-0.04	1.37	0.22	0.00	0.03	-1.9	-0.4	6.7	2.4	0.8	0.4	-4.18	0.01	0.74	1.11	-0.02	0.00
	20	-0.11	-0.05	1.34	0.23	0.04	0.05	-2.1	-0.4	6.7	2.5	0.9	0.4	-4.25	0.02	0.71	1.12	-0.01	0.00

TABLE A(III)-41 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.10	-0.02	1.05	0.24	-0.03	0.02	-1.8	-0.3	6.7	2.8	0.7	0.3	-4.06	0.08	0.76	1.10	-0.02	0.00
	10	-0.12	-0.03	1.10	0.27	-0.00	0.03	-2.0	-0.4	6.9	3.0	0.8	0.4	-4.22	0.10	0.76	1.10	-0.02	0.00
	15	-0.14	-0.05	1.02	0.28	0.04	0.05	-2.3	-0.5	6.9	3.1	0.8	0.5	-4.34	0.10	0.75	1.11	-0.02	0.00
	20	-0.16	-0.06	1.03	0.31	0.08	0.06	-2.5	-0.6	6.8	3.2	0.9	0.6	-4.41	0.11	0.73	1.11	-0.02	0.00
20	5	-0.08	-0.02	1.41	0.26	-0.07	0.02	-1.8	-0.3	7.1	3.0	0.7	0.3	-3.32	0.01	0.73	1.10	-0.02	0.00
	10	-0.08	-0.03	1.53	0.28	-0.05	0.03	-2.1	-0.4	7.2	3.2	0.8	0.5	-3.33	0.01	0.71	1.11	-0.02	0.00
	15	-0.07	-0.05	1.55	0.30	-0.02	0.05	-2.3	-0.5	7.0	3.4	0.9	0.6	-3.36	0.01	0.69	1.11	-0.02	0.00
	20	-0.08	-0.07	1.57	0.32	0.02	0.07	-2.6	-0.7	6.8	3.5	1.0	0.7	-3.46	0.01	0.68	1.12	-0.02	0.00
21	5	-0.07	-0.02	1.16	0.23	-0.04	0.02	-1.5	-0.3	6.4	2.8	0.7	0.4	-3.12	0.00	0.75	1.09	-0.02	0.00
	10	-0.07	-0.03	1.31	0.26	-0.03	0.04	-1.7	-0.4	6.3	3.0	0.8	0.5	-3.17	0.01	0.75	1.10	-0.02	0.00
	15	-0.07	-0.05	1.39	0.28	-0.01	0.05	-1.8	-0.5	6.1	3.1	0.9	0.6	-3.17	0.00	0.73	1.10	-0.02	0.00
	20	-0.08	-0.07	1.41	0.29	0.02	0.07	-1.8	-0.7	5.9	3.1	1.0	0.7	-3.17	0.00	0.72	1.11	-0.02	0.00
25	5	-0.10	-0.01	1.42	0.22	-0.06	0.02	-1.6	-0.2	6.6	2.4	0.6	0.3	-3.90	0.01	0.81	1.10	-0.02	0.00
	10	-0.12	-0.02	1.52	0.25	-0.04	0.02	-1.8	-0.3	6.5	2.6	0.8	0.4	-3.98	0.01	0.81	1.11	-0.01	0.00
	15	-0.14	-0.04	1.54	0.27	-0.01	0.04	-2.0	-0.4	6.3	2.7	0.9	0.4	-4.08	0.02	0.81	1.11	-0.01	0.00
	20	-0.17	-0.05	1.59	0.29	0.02	0.05	-2.1	-0.5	6.3	2.8	1.0	0.5	-4.19	0.03	0.82	1.12	-0.01	0.00
26	5	-0.15	-0.02	1.30	0.24	-0.05	0.02	-1.8	-0.3	6.6	3.1	0.7	0.4	-4.30	0.04	1.10	1.08	-0.03	0.00
	10	-0.16	-0.03	1.46	0.28	-0.03	0.03	-1.9	-0.4	7.1	3.2	0.9	0.5	-4.32	0.04	1.10	1.09	-0.03	0.00
	15	-0.16	-0.04	1.51	0.30	-0.00	0.05	-2.1	-0.6	7.3	3.3	0.9	0.6	-4.55	0.05	1.10	1.10	-0.03	0.00
	20	-0.17	-0.06	1.55	0.31	0.03	0.07	-2.2	-0.7	7.3	3.3	1.0	0.8	-4.72	0.06	1.10	1.10	-0.03	0.00
27	5	-0.10	-0.02	1.64	0.27	-0.06	0.04	-2.1	-0.3	6.9	4.2	0.8	0.5	-2.59	-0.15	1.07	1.11	-0.02	0.00
	10	-0.09	-0.04	1.81	0.29	-0.04	0.06	-2.3	-0.5	7.7	4.4	1.0	0.7	-2.49	-0.16	1.08	1.11	-0.02	0.00
	15	-0.05	-0.07	1.92	0.29	-0.02	0.09	-2.4	-0.8	8.3	4.5	1.2	0.9	-2.45	-0.16	1.08	1.12	-0.02	0.00
	20	-0.01	-0.11	1.98	0.28	0.03	0.12	-2.5	-1.0	8.8	4.5	1.3	1.2	-2.55	-0.16	1.09	1.12	-0.02	0.00

TABLE A(III)-42. SPRING PLOW SOYBEANS, FALL FERTILIZATION (A AND B SOILS)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.07	-0.05	-0.62	0.31	0.63	0.04	-4.8	-0.3	36.0	6.6	1.5	0.3	-0.31	-0.15	-0.01	1.16	0.01	0.00
	10	0.03	-0.11	-0.42	0.25	0.85	0.10	-6.5	-0.5	43.6	8.1	1.9	0.5	-0.26	-0.15	-0.01	1.16	0.01	0.00
	15	0.09	-0.18	-0.08	0.22	1.07	0.17	-8.7	-0.9	50.6	10.0	2.7	0.8	-0.32	-0.15	-0.01	1.17	0.01	0.00
	20	0.11	-0.28	0.32	0.24	1.32	0.26	-11.8	-1.7	58.4	12.6	4.3	1.5	-0.36	-0.14	-0.01	1.17	0.01	0.00
2	5	-0.04	-0.03	2.36	0.14	0.27	0.03	-2.8	-0.3	27.2	3.8	1.8	0.3	-0.13	-0.18	-0.00	1.17	0.01	0.00
	10	-0.04	-0.06	2.94	0.16	0.34	0.06	-3.6	-0.5	30.7	4.4	2.5	0.5	-0.05	-0.19	-0.00	1.17	0.01	0.00
	15	-0.06	-0.10	3.67	0.21	0.40	0.08	-4.4	-0.9	33.2	5.0	3.2	0.8	0.10	-0.20	-0.00	1.17	0.01	0.00
	20	-0.14	-0.13	4.16	0.30	0.49	0.11	-5.0	-1.4	34.5	5.3	4.3	1.1	0.06	-0.20	-0.00	1.17	0.01	0.00
3	5	-0.04	-0.01	0.63	0.08	0.23	0.01	-0.9	-0.1	14.6	1.4	1.1	0.1	-0.64	-0.18	-0.00	1.15	0.01	0.00
	10	-0.02	-0.02	0.86	0.07	0.25	0.02	-1.0	-0.2	15.3	1.5	1.3	0.2	-0.55	-0.20	-0.00	1.15	0.01	0.00
	15	-0.01	-0.03	1.04	0.06	0.27	0.03	-1.1	-0.2	15.6	1.5	1.4	0.2	-0.55	-0.20	-0.00	1.16	0.01	0.00
	20	-0.00	-0.04	1.25	0.06	0.29	0.03	-1.2	-0.2	15.8	1.6	1.4	0.2	-0.51	-0.21	0.00	1.16	0.01	0.00
4	5	-0.10	-0.02	-0.07	0.21	0.36	0.02	-2.2	-0.2	19.6	3.2	1.4	0.3	-1.31	-0.18	0.01	1.15	0.01	0.00
	10	-0.07	-0.04	0.10	0.20	0.42	0.04	-2.5	-0.4	22.0	3.6	2.0	0.4	-1.13	-0.20	0.01	1.15	0.01	0.00
	15	-0.05	-0.07	0.33	0.19	0.49	0.07	-2.9	-0.5	23.8	4.0	2.4	0.5	-1.12	-0.20	0.02	1.15	0.01	0.00
	20	-0.02	-0.10	0.62	0.19	0.56	0.09	-3.1	-0.8	24.4	4.2	3.1	0.8	-1.08	-0.21	0.02	1.16	0.01	0.00
5	5	-0.03	-0.01	0.65	0.11	0.25	0.02	-1.4	-0.2	16.0	2.3	1.2	0.2	-1.37	-0.28	0.04	1.15	0.01	0.00
	10	-0.01	-0.03	0.91	0.11	0.27	0.03	-1.6	-0.3	17.2	2.5	1.7	0.3	-1.25	-0.29	0.04	1.15	0.01	0.00
	15	0.01	-0.04	1.23	0.10	0.29	0.05	-1.8	-0.4	17.9	2.6	2.1	0.4	-1.22	-0.30	0.04	1.16	0.01	0.00
	20	0.01	-0.06	1.47	0.10	0.32	0.06	-1.8	-0.5	18.5	2.7	2.4	0.5	-1.32	-0.30	0.04	1.16	0.01	0.00
6	5	-0.16	-0.05	-0.66	0.33	0.51	0.05	-6.3	-0.4	37.5	8.4	1.8	0.5	-1.68	-0.17	-0.01	1.16	0.00	0.00
	10	-0.03	-0.12	-0.16	0.30	0.66	0.11	-9.3	-0.8	47.3	11.3	3.0	0.9	-0.68	-0.26	-0.01	1.17	0.00	0.00
	15	0.02	-0.20	0.55	0.32	0.85	0.19	-12.8	-1.6	56.1	14.4	4.3	1.5	-0.45	-0.28	-0.01	1.17	0.01	0.00
	20	-0.02	-0.31	1.54	0.42	1.04	0.28	-16.8	-3.2	63.5	17.6	7.0	2.9	-0.08	-0.31	-0.01	1.17	0.01	0.00
7	5	-0.19	-0.03	0.37	0.34	0.31	0.04	-4.3	-0.4	22.7	6.0	1.4	0.4	-2.23	-0.15	0.03	1.15	0.00	0.00
	10	-0.19	-0.07	0.85	0.39	0.38	0.08	-5.5	-0.7	27.3	7.4	2.4	0.8	-1.92	-0.19	0.04	1.16	0.00	0.00
	15	-0.23	-0.12	1.70	0.48	0.43	0.12	-6.9	-1.2	31.7	8.8	3.2	1.2	-1.75	-0.21	0.05	1.16	0.00	0.00
	20	-0.30	-0.18	2.56	0.60	0.49	0.18	-8.1	-2.1	34.8	9.9	4.5	2.0	-1.72	-0.21	0.05	1.16	0.00	0.00
8	5	-0.10	-0.01	0.70	0.19	0.17	0.02	-1.7	-0.2	13.0	2.6	1.0	0.2	-3.34	-0.05	0.11	1.13	-0.00	0.00
	10	-0.11	-0.02	0.88	0.20	0.19	0.03	-1.8	-0.3	14.0	2.8	1.4	0.3	-3.32	-0.06	0.11	1.13	-0.00	0.00
	15	-0.11	-0.04	1.04	0.21	0.21	0.05	-2.0	-0.4	14.6	3.0	1.7	0.4	-3.35	-0.06	0.12	1.13	-0.00	0.00
	20	-0.12	-0.06	1.24	0.22	0.24	0.06	-2.1	-0.5	14.8	3.0	2.1	0.5	-3.55	-0.04	0.13	1.14	-0.00	0.00
9	5	-0.03	-0.07	-0.41	0.46	0.41	0.07	-7.3	-0.6	35.4	11.2	1.8	0.7	-2.65	-0.20	-0.01	1.15	0.00	0.00
	10	0.02	-0.14	0.10	0.54	0.53	0.13	-12.1	-1.2	43.0	15.5	2.7	1.3	-2.62	-0.22	-0.00	1.16	0.00	0.00
	15	-0.02	-0.26	0.53	0.61	0.75	0.24	-17.6	-2.6	46.9	19.7	4.4	2.5	-3.04	-0.22	-0.00	1.16	0.00	0.00
	20	-0.17	-0.46	1.37	0.82	0.99	0.41	-25.7	-3.9	54.4	26.0	5.8	3.8	-3.17	-0.23	-0.00	1.16	0.00	0.00

TABLE A(III)-42 (CONT)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
10	5	-0.09	-0.04	0.12	0.42	0.27	0.05	-4.8	-0.4	22.8	8.4	1.4	0.6	-4.26	-0.02	0.04	1.13	0.00	0.00
	10	-0.11	-0.08	0.22	0.48	0.40	0.10	-6.6	-0.9	27.3	10.3	2.0	1.0	-4.56	0.00	0.05	1.14	0.00	0.00
	15	-0.05	-0.16	0.17	0.47	0.53	0.17	-8.4	-1.7	30.1	12.0	2.9	1.7	-4.58	-0.01	0.03	1.15	0.01	0.00
	20	-0.04	-0.28	0.04	0.48	0.72	0.29	-9.9	-3.4	30.7	13.0	4.7	3.3	-4.91	0.01	0.01	1.15	0.01	0.00
11	5	-0.08	-0.03	0.50	0.43	0.17	0.03	-3.0	-0.3	14.0	5.8	1.0	0.5	-2.94	-0.07	0.13	1.12	0.00	0.00
	10	-0.06	-0.06	0.52	0.46	0.23	0.06	-3.7	-0.6	16.1	6.7	1.4	0.7	-2.88	-0.07	0.13	1.13	0.00	0.00
	15	-0.04	-0.09	0.61	0.50	0.28	0.10	-4.4	-1.0	17.7	7.4	1.9	1.1	-2.94	-0.08	0.13	1.13	0.00	0.00
	20	-0.04	-0.15	0.75	0.52	0.35	0.15	-5.0	-1.5	18.9	7.9	2.4	1.6	-3.19	-0.06	0.14	1.14	0.00	0.00
12	5	-0.08	-0.02	0.09	0.23	0.18	0.02	-1.7	-0.2	10.8	2.9	0.8	0.3	-2.13	-0.11	0.04	1.11	0.01	0.00
	10	-0.07	-0.03	0.12	0.24	0.21	0.03	-2.0	-0.3	11.7	3.1	1.1	0.3	-2.24	-0.11	0.05	1.12	0.01	0.00
	15	-0.07	-0.05	0.15	0.25	0.24	0.05	-2.2	-0.4	12.4	3.3	1.3	0.4	-2.29	-0.11	0.05	1.12	0.01	0.00
	20	-0.04	-0.07	0.21	0.24	0.26	0.07	-2.4	-0.5	12.9	3.5	1.6	0.5	-2.30	-0.12	0.05	1.13	0.01	0.00
13	5	-0.07	-0.01	0.68	0.25	0.10	0.02	-1.4	-0.3	7.9	2.9	0.8	0.4	-4.06	0.05	0.27	1.09	-0.01	0.00
	10	-0.09	-0.02	0.76	0.28	0.11	0.03	-1.6	-0.4	8.5	3.1	1.1	0.5	-4.19	0.06	0.27	1.10	-0.01	0.00
	15	-0.08	-0.04	0.84	0.28	0.13	0.05	-1.7	-0.5	8.9	3.2	1.3	0.6	-4.25	0.07	0.29	1.10	-0.01	0.00
	20	-0.08	-0.06	0.88	0.30	0.15	0.07	-1.9	-0.6	9.4	3.3	1.5	0.7	-4.41	0.07	0.29	1.11	-0.01	0.00
14	5	-0.07	-0.01	0.87	0.23	0.08	0.02	-1.4	-0.3	7.8	2.9	0.9	0.4	-3.76	0.07	0.36	1.09	-0.01	0.01
	10	-0.08	-0.03	0.96	0.26	0.10	0.04	-1.6	-0.4	8.3	3.1	1.1	0.5	-3.84	0.08	0.37	1.09	-0.01	0.01
	15	-0.08	-0.05	1.00	0.28	0.12	0.05	-1.7	-0.5	8.7	3.2	1.3	0.6	-3.88	0.08	0.38	1.10	-0.01	0.01
	20	-0.08	-0.07	1.07	0.29	0.14	0.07	-1.8	-0.7	9.0	3.3	1.6	0.8	-3.94	0.09	0.40	1.11	-0.02	0.00
15	5	-0.06	-0.02	0.37	0.24	0.09	0.02	-1.3	-0.3	6.2	2.7	0.8	0.4	-3.15	-0.03	0.14	1.08	0.00	0.01
	10	-0.06	-0.03	0.41	0.25	0.11	0.04	-1.4	-0.3	6.5	2.8	1.0	0.5	-3.21	-0.02	0.14	1.09	0.00	0.01
	15	-0.05	-0.04	0.42	0.26	0.13	0.05	-1.4	-0.5	6.7	2.9	1.2	0.6	-3.15	-0.03	0.14	1.09	0.00	0.01
	20	-0.04	-0.06	0.42	0.26	0.15	0.07	-1.3	-0.6	6.8	2.8	1.4	0.8	-3.21	-0.03	0.13	1.10	0.00	0.01
16	5	-0.07	-0.01	0.67	0.19	0.23	0.01	-1.4	-0.2	14.7	2.6	1.0	0.2	-1.42	-0.23	0.09	1.14	0.01	0.00
	10	-0.04	-0.03	0.90	0.18	0.25	0.03	-1.7	-0.2	16.0	2.8	1.2	0.3	-1.27	-0.25	0.10	1.14	0.01	0.00
	15	-0.03	-0.04	1.05	0.19	0.27	0.04	-1.9	-0.3	17.0	3.0	1.4	0.3	-1.29	-0.25	0.10	1.14	0.01	0.00
	20	-0.03	-0.06	1.27	0.19	0.29	0.06	-2.1	-0.4	17.6	3.2	1.6	0.4	-1.39	-0.25	0.11	1.15	0.01	0.00
17	5	-0.08	-0.01	0.79	0.16	0.19	0.01	-1.1	-0.1	12.5	1.9	1.0	0.2	-3.62	-0.13	0.16	1.13	0.00	0.00
	10	-0.07	-0.02	1.05	0.17	0.20	0.02	-1.2	-0.2	13.5	2.1	1.2	0.2	-3.35	-0.17	0.18	1.14	-0.00	0.00
	15	-0.07	-0.03	1.30	0.17	0.21	0.03	-1.3	-0.2	14.2	2.2	1.4	0.3	-3.57	-0.15	0.19	1.14	-0.00	0.00
	20	-0.08	-0.04	1.52	0.18	0.22	0.04	-1.4	-0.3	14.7	2.3	1.7	0.3	-3.75	-0.14	0.20	1.14	-0.00	0.00
18	5	-0.09	-0.01	1.23	0.19	0.08	0.01	-1.2	-0.2	9.0	2.1	0.8	0.2	-4.19	0.01	0.31	1.10	-0.01	0.00
	10	-0.09	-0.02	1.40	0.21	0.08	0.02	-1.4	-0.2	9.6	2.3	1.0	0.3	-4.12	0.01	0.32	1.11	-0.01	0.00
	15	-0.10	-0.03	1.54	0.22	0.09	0.03	-1.5	-0.3	10.0	2.4	1.2	0.3	-4.18	0.01	0.34	1.11	-0.01	0.00
	20	-0.10	-0.04	1.69	0.23	0.10	0.04	-1.6	-0.4	10.3	2.4	1.3	0.4	-4.25	0.02	0.35	1.12	-0.01	0.00

TABLE A(III)-42 (CONT)

REGION	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
			DISSOLVED N IN RUNOFF					DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
19	5	-0.09	-0.01	1.36	0.23	0.06	0.02	-1.5	-0.2	9.1	2.7	0.9	0.3	-4.06	0.08	0.39	1.10	-0.01	0.00
	10	-0.11	-0.03	1.54	0.27	0.07	0.03	-1.7	-0.3	9.7	2.9	1.1	0.4	-4.22	0.10	0.41	1.10	-0.02	0.00
	15	-0.12	-0.04	1.67	0.28	0.08	0.04	-1.8	-0.4	10.2	3.0	1.3	0.5	-4.34	0.10	0.43	1.11	-0.02	0.00
	20	-0.13	-0.05	1.74	0.30	0.10	0.06	-2.0	-0.5	10.5	3.1	1.4	0.6	-4.41	0.11	0.43	1.11	-0.02	0.00
20	5	-0.07	-0.02	0.81	0.26	0.10	0.02	-1.6	-0.2	8.8	2.9	0.8	0.3	-3.32	0.01	0.26	1.10	-0.01	0.00
	10	-0.07	-0.03	0.92	0.28	0.11	0.03	-1.8	-0.3	9.3	3.1	1.1	0.4	-3.33	0.01	0.27	1.11	-0.01	0.00
	15	-0.07	-0.05	0.99	0.30	0.13	0.05	-2.0	-0.5	9.8	3.3	1.3	0.6	-3.36	0.01	0.28	1.11	-0.01	0.00
	20	-0.07	-0.06	1.10	0.32	0.15	0.06	-2.1	-0.6	10.3	3.4	1.5	0.7	-3.46	0.01	0.29	1.12	-0.01	0.00
21	5	-0.06	-0.02	0.59	0.23	0.10	0.02	-1.4	-0.2	7.4	2.8	0.8	0.3	-3.12	0.00	0.22	1.09	-0.00	0.00
	10	-0.07	-0.03	0.65	0.26	0.11	0.03	-1.5	-0.3	7.8	2.9	1.0	0.5	-3.17	0.01	0.22	1.10	-0.00	0.00
	15	-0.07	-0.04	0.67	0.28	0.14	0.05	-1.5	-0.5	8.2	3.0	1.2	0.6	-3.17	0.00	0.23	1.10	-0.00	0.00
	20	-0.07	-0.06	0.73	0.29	0.16	0.07	-1.5	-0.6	8.4	3.1	1.4	0.7	-3.17	0.00	0.23	1.11	-0.00	0.00
25	5	-0.09	-0.01	0.62	0.22	0.12	0.02	-1.3	-0.2	9.3	2.4	0.9	0.3	-3.90	0.01	0.15	1.10	0.00	0.00
	10	-0.11	-0.02	0.70	0.25	0.14	0.02	-1.4	-0.3	10.0	2.5	1.1	0.3	-3.98	0.01	0.15	1.11	0.00	0.00
	15	-0.13	-0.03	0.78	0.27	0.15	0.04	-1.4	-0.3	10.3	2.6	1.3	0.4	-4.08	0.02	0.15	1.11	0.00	0.00
	20	-0.14	-0.04	0.87	0.29	0.17	0.05	-1.5	-0.4	10.6	2.7	1.6	0.5	-4.19	0.03	0.15	1.12	0.00	0.00
26	5	-0.13	-0.01	0.09	0.24	0.12	0.02	-1.5	-0.2	7.9	3.1	0.8	0.4	-4.30	0.04	0.04	1.08	0.00	0.00
	10	-0.14	-0.02	0.11	0.28	0.13	0.03	-1.7	-0.4	8.2	3.2	1.1	0.5	-4.32	0.04	0.04	1.09	0.00	0.00
	15	-0.14	-0.04	0.11	0.30	0.15	0.05	-1.8	-0.5	8.2	3.3	1.4	0.6	-4.55	0.05	0.04	1.10	0.00	0.00
	20	-0.15	-0.06	0.10	0.31	0.18	0.07	-1.9	-0.7	8.5	3.3	1.6	0.8	-4.72	0.06	0.04	1.10	0.00	0.00
27	5	-0.10	-0.02	0.04	0.27	0.12	0.04	-1.8	-0.3	8.9	4.1	0.9	0.5	-2.59	-0.15	0.02	1.11	0.00	0.00
	10	-0.08	-0.04	0.02	0.29	0.16	0.06	-2.0	-0.5	9.2	4.4	1.3	0.7	-2.49	-0.16	0.01	1.11	0.00	0.00
	15	-0.04	-0.07	0.03	0.29	0.21	0.08	-2.2	-0.7	9.3	4.4	1.6	0.9	-2.45	-0.16	0.01	1.12	0.00	0.00
	20	-0.00	-0.10	-0.03	0.28	0.27	0.12	-2.3	-1.0	9.8	4.4	1.7	1.1	-2.55	-0.16	0.00	1.12	0.00	0.00

TABLE A(III)-43. SPRING FLOW SOYBEANS (C AND D SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.79	0.09	-1.73	48.72	10	5	2.55	-1.21	-2.49	58.91	19	5	3.88	-5.39	-3.85	74.24
	10	1.70	0.16	-1.58	36.92		10	2.46	-1.16	-2.29	45.54		10	3.89	-5.52	-3.81	67.30
	15	1.62	0.07	-1.47	28.26		15	2.36	-1.17	-2.18	35.84		15	3.85	-5.60	-3.74	62.27
	20	1.53	0.08	-1.37	20.76		20	2.27	-1.17	-2.06	27.95		20	3.81	-5.72	-3.70	58.15
2	5	2.68	-2.31	-2.65	56.34	11	5	3.14	-2.69	-3.10	67.64	20	5	3.92	-4.20	-3.91	75.17
	10	2.61	-2.19	-2.51	46.00		10	3.06	-2.67	-2.96	56.39		10	3.91	-4.33	-3.87	67.75
	15	2.53	-2.24	-2.40	38.58		15	3.03	-2.79	-2.86	48.17		15	3.89	-4.47	-3.83	62.11
	20	2.45	-2.20	-2.31	33.08		20	2.96	-2.87	-2.76	41.35		20	3.85	-4.60	-3.76	57.29
3	5	3.45	-1.85	-3.45	69.93	12	5	3.37	-1.54	-3.35	70.08	21	5	4.14	-3.42	-4.13	76.19
	10	3.49	-2.13	-3.48	64.45		10	3.40	-1.69	-3.34	62.29		10	4.15	-3.52	-4.11	68.98
	15	3.48	-2.28	-3.48	61.32		15	3.42	-1.86	-3.32	56.73		15	4.13	-3.67	-4.07	63.65
	20	3.47	-2.48	-3.47	58.77		20	3.40	-2.11	-3.28	52.12		20	4.09	-3.81	-4.04	59.16
4	5	2.91	-1.85	-2.88	61.22	13	5	4.18	-3.49	-4.16	76.81	25	5	3.88	-4.83	-3.86	76.01
	10	2.94	-2.21	-2.84	51.88		10	4.15	-3.53	-4.06	69.03		10	3.90	-4.94	-3.85	68.60
	15	2.90	-2.42	-2.74	45.32		15	4.14	-3.76	-4.00	63.35		15	3.90	-5.15	-3.85	63.60
	20	2.86	-2.60	-2.74	40.36		20	4.13	-3.94	-3.91	58.34		20	3.88	-5.30	-3.83	59.65
5	5	3.23	-3.09	-3.21	65.68	14	5	4.24	-4.47	-4.22	76.87	26	5	3.77	-3.74	-3.76	71.85
	10	3.25	-3.26	-3.18	57.98		10	4.22	-4.57	-4.15	69.50		10	3.82	-4.00	-3.80	64.60
	15	3.24	-3.50	-3.17	52.89		15	4.18	-4.67	-4.08	63.79		15	3.85	-4.27	-3.84	60.35
	20	3.23	-3.63	-3.15	48.68		20	4.14	-4.85	-4.02	59.10		20	3.86	-4.37	-3.84	56.90
6	5	1.80	-1.19	-1.70	45.32	15	5	4.21	-2.69	-4.21	74.60	27	5	3.52	-1.64	-3.51	66.63
	10	1.73	-1.41	-1.48	31.39		10	4.23	-2.98	-4.21	67.91		10	3.55	-1.87	-3.54	58.95
	15	1.63	-1.35	-1.27	22.69		15	4.23	-3.20	-4.20	63.21		15	3.58	-2.21	-3.58	53.90
	20	1.54	-1.34	-1.16	16.36		20	4.21	-3.34	-4.20	59.39		20	3.58	-2.41	-3.57	49.91
7	5	2.45	-2.82	-2.40	55.86	16	5	3.14	-2.24	-3.11	67.33						
	10	2.48	-3.20	-2.33	43.88		10	3.12	-2.47	-3.01	59.75						
	15	2.43	-3.39	-2.13	35.07		15	3.09	-2.58	-2.91	54.12						
	20	2.39	-3.48	-1.98	28.16		20	3.08	-2.77	-2.89	49.91						
8	5	3.31	-3.14	-3.28	67.45	17	5	3.50	-4.10	-3.48	72.22						
	10	3.38	-3.48	-3.28	59.58		10	3.49	-4.21	-3.42	64.77						
	15	3.39	-3.75	-3.26	54.28		15	3.45	-4.33	-3.37	59.46						
	20	3.38	-4.01	-3.24	50.26		20	3.41	-4.40	-3.33	54.96						
9	5	1.94	-0.15	-1.85	47.75	18	5	3.99	-4.95	-3.99	77.06						
	10	1.79	-0.05	-1.59	32.53		10	3.98	-5.04	-3.94	70.52						
	15	1.72	-0.23	-1.44	22.79		15	3.93	-5.09	-3.88	65.77						
	20	1.64	-0.38	-1.21	15.57		20	3.90	-5.20	-3.85	61.84						

TABLE A(III)-44. SPRING PLOW SOYBEANS, SPRING FERTILIZATION (C AND D SOILS)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	0.00	-0.06	8.00	0.39	-0.40	0.04	-6.7	-0.4	26.9	7.2	1.2	0.4	0.09	-0.16	1.13	1.16	-0.04	0.00
	10	0.11	-0.13	8.44	0.35	-0.29	0.09	-9.2	-0.7	29.8	9.1	1.8	0.6	0.12	-0.16	1.13	1.16	-0.05	0.00
	15	0.20	-0.21	8.56	0.32	-0.11	0.16	-12.0	-1.3	33.6	11.2	3.1	1.1	0.11	-0.16	1.14	1.17	-0.05	0.00
	20	0.24	-0.32	8.82	0.33	0.11	0.24	-15.1	-2.8	38.5	13.5	6.2	2.3	0.09	-0.15	1.14	1.17	-0.05	0.00
2	5	-0.03	-0.04	6.19	0.26	-0.35	0.02	-4.0	-0.5	20.0	4.1	1.7	0.4	0.09	-0.19	0.92	1.16	-0.03	0.00
	10	0.01	-0.08	6.72	0.27	-0.29	0.05	-5.1	-0.8	20.9	4.8	2.2	0.6	0.13	-0.19	0.92	1.16	-0.03	0.00
	15	0.03	-0.13	6.94	0.29	-0.18	0.08	-6.1	-1.2	21.0	5.3	3.3	1.0	0.19	-0.19	0.90	1.17	-0.03	0.00
	20	-0.00	-0.17	7.10	0.32	-0.06	0.12	-6.6	-1.9	20.4	5.5	4.9	1.4	0.17	-0.19	0.90	1.17	-0.03	0.00
3	5	-0.04	-0.02	4.30	0.15	-0.25	0.01	-1.6	-0.2	10.3	1.6	1.0	0.2	-0.18	-0.21	0.75	1.15	-0.02	0.00
	10	-0.02	-0.03	4.52	0.15	-0.23	0.01	-1.8	-0.3	10.1	1.6	1.1	0.2	-0.12	-0.22	0.74	1.15	-0.01	0.00
	15	-0.01	-0.04	4.60	0.14	-0.19	0.02	-1.9	-0.3	10.0	1.7	1.2	0.2	-0.11	-0.22	0.73	1.15	-0.01	0.00
	20	0.01	-0.05	4.67	0.14	-0.16	0.03	-2.0	-0.4	9.9	1.8	1.3	0.3	-0.09	-0.23	0.72	1.15	-0.01	0.00
4	5	-0.03	-0.03	5.34	0.26	-0.30	0.02	-3.1	-0.3	14.0	3.5	1.1	0.3	-0.25	-0.25	0.91	1.15	-0.02	0.00
	10	0.02	-0.06	5.47	0.24	-0.24	0.04	-3.7	-0.6	14.6	3.9	1.6	0.5	-0.15	-0.26	0.90	1.16	-0.02	0.00
	15	0.06	-0.09	5.55	0.22	-0.17	0.07	-4.2	-0.8	14.9	4.3	2.1	0.7	-0.13	-0.27	0.90	1.16	-0.02	0.00
	20	0.11	-0.13	5.62	0.20	-0.09	0.10	-4.3	-1.2	14.5	4.3	2.9	1.0	-0.09	-0.28	0.90	1.16	-0.02	0.00
5	5	-0.02	-0.02	4.35	0.22	-0.26	0.01	-2.2	-0.3	11.1	2.5	1.0	0.3	-0.33	-0.35	0.73	1.15	-0.01	0.00
	10	0.01	-0.04	4.55	0.22	-0.22	0.03	-2.5	-0.4	11.2	2.7	1.3	0.4	-0.26	-0.36	0.72	1.15	-0.01	0.00
	15	0.04	-0.06	4.53	0.21	-0.17	0.04	-2.7	-0.5	11.0	2.8	1.6	0.5	-0.22	-0.37	0.71	1.15	-0.01	0.00
	20	0.05	-0.09	4.53	0.20	-0.11	0.06	-2.9	-0.7	10.7	2.9	2.0	0.6	-0.28	-0.37	0.71	1.16	-0.01	0.00
6	5	0.05	-0.07	7.73	0.45	-0.38	0.04	-7.7	-0.5	28.5	8.6	1.2	0.5	0.12	-0.22	1.19	1.16	-0.04	0.00
	10	0.18	-0.14	8.40	0.43	-0.30	0.09	-11.7	-0.9	32.7	11.8	1.9	0.8	0.28	-0.24	1.19	1.17	-0.04	0.00
	15	0.29	-0.24	8.67	0.41	-0.13	0.17	-16.3	-1.8	38.4	15.3	3.6	1.5	0.29	-0.23	1.20	1.17	-0.05	0.00
	20	0.37	-0.38	8.97	0.41	0.11	0.28	-22.4	-3.4	47.1	19.9	6.8	3.0	0.34	-0.24	1.19	1.17	-0.05	0.00
7	5	-0.07	-0.05	5.44	0.42	-0.28	0.04	-5.2	-0.5	16.5	6.1	1.0	0.5	-0.34	-0.30	0.68	1.16	0.01	0.00
	10	-0.02	-0.10	5.38	0.42	-0.18	0.08	-6.5	-0.9	18.4	7.3	1.7	0.9	-0.22	-0.31	0.67	1.16	0.02	0.00
	15	0.01	-0.16	5.31	0.46	-0.06	0.13	-7.9	-1.4	20.1	8.5	2.6	1.4	-0.12	-0.33	0.65	1.16	0.02	0.00
	20	0.01	-0.24	5.38	0.52	0.07	0.18	-8.5	-2.6	20.5	9.0	4.4	2.4	-0.12	-0.33	0.64	1.17	0.02	0.00
8	5	-0.05	-0.02	3.95	0.27	-0.23	0.01	-2.3	-0.3	9.2	2.7	0.8	0.3	-0.91	-0.22	1.07	1.13	-0.04	0.00
	10	-0.03	-0.04	4.25	0.28	-0.21	0.03	-2.6	-0.4	9.8	3.0	1.0	0.4	-0.88	-0.22	1.06	1.13	-0.04	0.00
	15	0.00	-0.07	4.42	0.28	-0.18	0.04	-2.9	-0.5	10.1	3.2	1.1	0.5	-0.83	-0.23	1.07	1.14	-0.04	0.00
	20	0.04	-0.09	4.48	0.27	-0.13	0.06	-3.1	-0.7	10.0	3.3	1.4	0.6	-0.85	-0.23	1.07	1.14	-0.04	0.00
9	5	0.00	-0.07	8.10	0.71	-0.40	0.05	-9.1	-0.8	28.8	11.9	1.4	0.8	-0.53	-0.35	1.23	1.16	-0.03	0.00
	10	0.03	-0.15	8.92	0.87	-0.35	0.10	-14.7	-1.7	32.5	16.6	2.7	1.6	-0.44	-0.37	1.24	1.17	-0.03	0.00
	15	-0.02	-0.28	9.21	1.02	-0.17	0.22	-20.2	-3.7	36.7	20.5	5.8	3.4	-0.49	-0.40	1.24	1.17	-0.03	0.00
	20	-0.17	-0.50	9.83	1.29	0.12	0.40	-31.0	-4.5	49.1	28.9	7.2	4.4	-0.42	-0.43	1.23	1.17	-0.03	0.00

TABLE A(III)-44 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.04	-0.05	6.40	0.63	-0.36	0.04	-5.8	-0.6	18.5	8.8	1.1	0.7	-1.63	-0.23	1.20	1.15	-0.04	0.00
	10	-0.01	-0.10	6.77	0.70	-0.31	0.08	-8.1	-1.1	19.5	10.8	1.7	1.2	-1.73	-0.23	1.21	1.15	-0.04	0.00
	15	0.05	-0.19	7.01	0.75	-0.21	0.16	-10.0	-2.3	20.2	12.4	2.9	2.2	-1.69	-0.25	1.21	1.16	-0.04	0.00
	20	0.08	-0.32	7.13	0.82	-0.04	0.28	-10.2	-4.8	18.9	12.1	6.0	4.5	-1.79	-0.25	1.20	1.16	-0.04	0.00
11	5	-0.04	-0.04	5.24	0.59	-0.34	0.02	-3.5	-0.4	11.3	6.0	0.8	0.6	-1.24	-0.21	1.14	1.13	-0.05	0.00
	10	0.00	-0.07	5.64	0.64	-0.33	0.05	-4.5	-0.8	11.3	6.9	1.1	0.8	-1.17	-0.22	1.14	1.13	-0.05	0.00
	15	0.06	-0.11	6.00	0.69	-0.30	0.09	-5.4	-1.2	11.2	7.6	1.5	1.3	-1.16	-0.23	1.14	1.14	-0.05	0.00
	20	0.12	-0.18	6.13	0.71	-0.23	0.15	-5.9	-2.0	11.0	8.0	2.2	1.9	-1.23	-0.22	1.15	1.14	-0.05	0.00
12	5	-0.04	-0.02	3.61	0.30	-0.21	0.01	-2.2	-0.3	8.4	3.1	0.7	0.3	-0.80	-0.21	1.02	1.12	-0.03	0.00
	10	-0.02	-0.04	3.79	0.30	-0.19	0.03	-2.5	-0.4	8.7	3.3	0.8	0.4	-0.82	-0.22	1.01	1.13	-0.03	0.00
	15	0.01	-0.06	3.95	0.30	-0.17	0.05	-2.8	-0.6	8.7	3.5	1.0	0.5	-0.83	-0.22	1.01	1.13	-0.03	0.00
	20	0.05	-0.09	4.05	0.29	-0.13	0.07	-3.1	-0.7	8.4	3.6	1.2	0.7	-0.80	-0.23	1.01	1.13	-0.03	0.00
13	5	-0.07	-0.02	2.77	0.35	-0.17	0.01	-1.7	-0.3	6.0	2.9	0.7	0.4	-2.71	-0.06	0.89	1.09	-0.03	0.00
	10	-0.07	-0.03	2.91	0.38	-0.16	0.03	-1.9	-0.5	6.2	3.1	0.8	0.5	-2.79	-0.06	0.89	1.10	-0.03	0.00
	15	-0.05	-0.05	3.01	0.39	-0.13	0.04	-2.1	-0.6	6.0	3.2	0.9	0.7	-2.83	-0.06	0.88	1.10	-0.03	0.00
	20	-0.04	-0.08	3.06	0.40	-0.10	0.07	-2.4	-0.8	5.7	3.4	1.0	0.8	-2.93	-0.06	0.88	1.11	-0.03	0.00
14	5	-0.07	-0.02	2.49	0.35	-0.16	0.02	-1.7	-0.3	5.9	3.0	0.8	0.4	-2.67	-0.03	0.84	1.09	-0.03	0.01
	10	-0.07	-0.04	2.67	0.38	-0.14	0.03	-1.9	-0.5	6.1	3.2	0.8	0.6	-2.71	-0.02	0.83	1.10	-0.03	0.01
	15	-0.06	-0.06	2.73	0.40	-0.11	0.05	-2.1	-0.7	6.0	3.3	0.9	0.7	-2.72	-0.02	0.82	1.10	-0.03	0.00
	20	-0.05	-0.08	2.77	0.41	-0.07	0.07	-2.2	-0.9	5.8	3.4	1.0	0.9	-2.75	-0.02	0.81	1.11	-0.03	0.00
15	5	-0.05	-0.02	2.29	0.33	-0.13	0.02	-1.5	-0.3	5.4	2.8	0.6	0.4	-2.03	-0.12	0.85	1.09	-0.02	0.00
	10	-0.04	-0.04	2.46	0.35	-0.12	0.03	-1.6	-0.5	5.4	2.9	0.7	0.6	-2.03	-0.12	0.85	1.09	-0.02	0.00
	15	-0.01	-0.05	2.59	0.36	-0.11	0.05	-1.5	-0.6	5.2	2.9	0.8	0.7	-1.97	-0.13	0.84	1.10	-0.02	0.00
	20	0.01	-0.08	2.65	0.37	-0.08	0.07	-1.4	-0.9	4.8	2.8	0.9	0.9	-2.01	-0.13	0.83	1.10	-0.02	0.00
16	5	-0.05	-0.02	5.03	0.29	-0.32	0.01	-2.2	-0.3	9.9	2.8	0.8	0.3	-0.45	-0.30	0.88	1.14	-0.02	0.00
	10	-0.02	-0.04	5.21	0.28	-0.30	0.02	-2.7	-0.4	10.0	3.1	0.9	0.3	-0.35	-0.31	0.87	1.14	-0.02	0.00
	15	0.01	-0.06	5.28	0.28	-0.26	0.04	-3.1	-0.4	10.1	3.3	1.1	0.4	-0.36	-0.32	0.87	1.15	-0.02	0.00
	20	0.04	-0.08	5.25	0.27	-0.21	0.05	-3.4	-0.5	10.2	3.5	1.3	0.5	-0.40	-0.32	0.85	1.15	-0.02	0.00
17	5	-0.11	-0.01	4.48	0.31	-0.30	-0.00	-1.6	-0.2	8.3	2.0	0.7	0.2	-1.55	-0.30	0.91	1.13	-0.03	0.00
	10	-0.08	-0.03	4.96	0.33	-0.30	0.01	-1.9	-0.3	8.3	2.2	0.9	0.3	-1.32	-0.32	0.90	1.13	-0.03	0.00
	15	-0.06	-0.05	4.99	0.33	-0.26	0.02	-2.2	-0.4	8.4	2.3	1.0	0.3	-1.34	-0.33	0.89	1.14	-0.03	0.00
	20	-0.04	-0.07	5.06	0.33	-0.22	0.03	-2.4	-0.5	8.4	2.5	1.2	0.4	-1.39	-0.33	0.89	1.14	-0.03	0.00
18	5	-0.09	-0.02	3.49	0.32	-0.23	0.00	-1.6	-0.2	6.2	2.2	0.7	0.3	-2.33	-0.15	0.92	1.11	-0.03	0.00
	10	-0.08	-0.03	3.86	0.35	-0.24	0.01	-1.8	-0.3	6.4	2.4	0.8	0.3	-2.21	-0.16	0.91	1.11	-0.03	0.00
	15	-0.07	-0.04	3.92	0.36	-0.21	0.03	-2.0	-0.4	6.6	2.5	0.8	0.4	-2.24	-0.16	0.91	1.11	-0.03	0.00
	20	-0.06	-0.06	3.98	0.37	-0.18	0.04	-2.1	-0.5	6.6	2.5	0.9	0.5	-2.27	-0.16	0.90	1.12	-0.03	0.00

TABLE A(III)-44 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.10	-0.02	3.38	0.39	-0.23	0.01	-1.8	-0.3	6.6	2.8	0.7	0.3	-2.54	-0.06	0.89	1.10	-0.03	0.00
	10	-0.09	-0.03	3.74	0.43	-0.23	0.02	-2.1	-0.4	6.8	3.0	0.7	0.4	-2.58	-0.06	0.88	1.11	-0.03	0.00
	15	-0.09	-0.05	3.77	0.45	-0.19	0.03	-2.3	-0.5	6.7	3.1	0.8	0.5	-2.65	-0.05	0.88	1.11	-0.03	0.00
	20	-0.09	-0.07	3.85	0.47	-0.16	0.05	-2.5	-0.6	6.5	3.2	0.9	0.6	-2.69	-0.05	0.87	1.12	-0.03	0.00
20	5	-0.07	-0.02	3.58	0.40	-0.24	0.01	-1.9	-0.3	7.0	3.0	0.7	0.4	-1.91	-0.11	0.92	1.10	-0.04	0.00
	10	-0.05	-0.04	3.88	0.43	-0.24	0.02	-2.2	-0.5	6.9	3.2	0.8	0.5	-1.90	-0.12	0.92	1.11	-0.04	0.00
	15	-0.03	-0.06	4.07	0.46	-0.22	0.04	-2.4	-0.6	6.7	3.4	0.9	0.6	-1.90	-0.12	0.91	1.11	-0.03	0.00
	20	-0.01	-0.08	4.22	0.48	-0.20	0.06	-2.6	-0.8	6.4	3.5	1.0	0.8	-1.94	-0.12	0.90	1.12	-0.03	0.00
21	5	-0.05	-0.02	2.81	0.34	-0.17	0.02	-1.6	-0.3	6.2	2.9	0.6	0.4	-1.88	-0.10	0.94	1.10	-0.03	0.00
	10	-0.04	-0.04	3.15	0.38	-0.17	0.03	-1.7	-0.5	5.9	3.0	0.7	0.5	-1.88	-0.11	0.94	1.10	-0.03	0.00
	15	-0.02	-0.06	3.35	0.40	-0.16	0.04	-1.8	-0.6	5.7	3.1	0.9	0.7	-1.86	-0.11	0.94	1.11	-0.03	0.00
	20	0.00	-0.08	3.44	0.42	-0.13	0.06	-1.9	-0.8	5.5	3.1	1.0	0.8	-1.86	-0.11	0.93	1.11	-0.03	0.00
25	5	-0.07	-0.02	3.69	0.34	-0.25	0.01	-1.7	-0.2	6.3	2.5	0.6	0.3	-1.98	-0.17	0.82	1.11	-0.02	0.00
	10	-0.07	-0.03	3.78	0.36	-0.23	0.02	-1.9	-0.4	6.2	2.6	0.8	0.4	-2.04	-0.16	0.82	1.12	-0.01	0.00
	15	-0.07	-0.05	3.79	0.37	-0.20	0.03	-2.1	-0.5	6.1	2.7	0.9	0.5	-2.12	-0.16	0.82	1.12	-0.01	0.00
	20	-0.07	-0.06	3.83	0.38	-0.16	0.04	-2.2	-0.6	6.0	2.8	1.1	0.6	-2.20	-0.15	0.83	1.12	-0.01	0.00
26	5	-0.12	-0.02	2.98	0.37	-0.18	0.01	-1.8	-0.3	6.7	3.1	0.7	0.4	-2.73	-0.10	1.11	1.10	-0.03	0.00
	10	-0.12	-0.03	3.26	0.42	-0.17	0.02	-2.0	-0.5	7.1	3.3	0.8	0.6	-2.72	-0.11	1.11	1.11	-0.03	0.00
	15	-0.10	-0.05	3.42	0.45	-0.15	0.04	-2.1	-0.6	7.1	3.3	0.9	0.7	-2.86	-0.10	1.11	1.11	-0.03	0.00
	20	-0.09	-0.08	3.47	0.47	-0.12	0.06	-2.2	-0.8	7.1	3.3	1.0	0.9	-3.00	-0.09	1.11	1.12	-0.03	0.00
27	5	-0.07	-0.03	2.75	0.36	-0.14	0.03	-2.2	-0.4	7.0	4.3	0.8	0.5	-1.30	-0.25	1.12	1.12	-0.03	0.00
	10	-0.04	-0.05	2.96	0.39	-0.12	0.05	-2.3	-0.7	7.8	4.4	1.1	0.8	-1.20	-0.25	1.12	1.13	-0.03	0.00
	15	0.01	-0.08	3.10	0.40	-0.09	0.08	-2.3	-1.0	8.4	4.4	1.2	1.1	-1.14	-0.26	1.12	1.13	-0.02	0.00
	20	0.07	-0.13	3.18	0.40	-0.04	0.12	-2.3	-1.3	8.7	4.3	1.4	1.4	-1.19	-0.26	1.13	1.14	-0.02	0.00

TABLE A(III)-45. SPRING PLOW SOYBEANS, FALL FERTILIZATION (C AND D SOILS)

REGION			DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF				
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
1	5	-0.02	-0.04	-0.93	0.39	0.57	0.03	-5.1	-0.3	38.3	6.9	1.7	0.4	0.09	-0.16	-0.01	1.16	0.01	0.00
	10	0.07	-0.10	-0.87	0.36	0.77	0.09	-7.1	-0.6	46.6	8.7	2.5	0.6	0.12	-0.16	-0.01	1.16	0.01	0.00
	15	0.15	-0.17	-0.71	0.33	0.99	0.15	-9.5	-1.2	54.0	10.7	3.7	1.1	0.11	-0.16	-0.01	1.17	0.01	0.00
	20	0.20	-0.27	-0.36	0.34	1.23	0.23	-12.3	-2.7	60.7	13.0	6.7	2.3	0.09	-0.15	-0.02	1.17	0.01	0.00
2	5	-0.04	-0.03	0.62	0.27	0.41	0.02	-2.9	-0.4	28.0	3.9	2.0	0.4	0.09	-0.19	-0.01	1.16	0.01	0.00
	10	-0.01	-0.06	0.87	0.28	0.51	0.05	-3.7	-0.6	31.4	4.5	2.9	0.6	0.13	-0.19	-0.01	1.16	0.01	0.00
	15	0.02	-0.10	1.24	0.29	0.61	0.08	-4.4	-1.1	33.6	5.0	4.0	0.9	0.19	-0.19	-0.01	1.17	0.01	0.00
	20	0.01	-0.14	1.61	0.32	0.71	0.11	-4.8	-1.8	34.0	5.2	5.4	1.4	0.17	-0.19	-0.01	1.17	0.01	0.00
3	5	-0.05	-0.01	0.17	0.15	0.27	0.01	-0.9	-0.1	15.2	1.4	1.2	0.2	-0.18	-0.21	-0.01	1.15	0.01	0.00
	10	-0.03	-0.02	0.32	0.15	0.29	0.01	-1.0	-0.2	15.8	1.5	1.5	0.2	-0.12	-0.22	-0.01	1.15	0.01	0.00
	15	-0.02	-0.03	0.47	0.15	0.32	0.02	-1.1	-0.2	16.0	1.6	1.6	0.2	-0.11	-0.22	-0.01	1.15	0.01	0.00
	20	-0.01	-0.04	0.64	0.14	0.34	0.03	-1.2	-0.3	16.0	1.6	1.6	0.3	-0.09	-0.23	-0.01	1.15	0.01	0.00
4	5	-0.03	-0.02	-0.44	0.26	0.37	0.02	-2.3	-0.3	20.4	3.3	1.6	0.3	-0.25	-0.25	-0.01	1.15	0.01	0.00
	10	-0.00	-0.05	-0.39	0.24	0.44	0.04	-2.6	-0.4	22.7	3.7	2.3	0.5	-0.15	-0.26	-0.01	1.16	0.01	0.00
	15	0.03	-0.07	-0.26	0.23	0.52	0.06	-2.9	-0.7	24.3	4.0	3.0	0.7	-0.13	-0.27	-0.00	1.16	0.01	0.00
	20	0.07	-0.10	-0.08	0.21	0.60	0.09	-3.0	-1.1	24.3	4.1	3.9	1.0	-0.09	-0.28	-0.00	1.16	0.01	0.00
5	5	-0.02	-0.02	-0.00	0.22	0.29	0.01	-1.5	-0.2	16.4	2.4	1.4	0.3	-0.33	-0.35	0.00	1.15	0.01	0.00
	10	0.00	-0.03	0.12	0.22	0.33	0.02	-1.7	-0.3	17.5	2.6	1.9	0.3	-0.26	-0.36	0.01	1.15	0.01	0.00
	15	0.02	-0.05	0.29	0.21	0.37	0.04	-1.8	-0.4	18.3	2.7	2.3	0.5	-0.22	-0.37	0.01	1.15	0.01	0.00
	20	0.03	-0.06	0.46	0.21	0.40	0.05	-1.8	-0.6	18.6	2.7	2.8	0.6	-0.28	-0.37	0.01	1.16	0.01	0.00
6	5	0.03	-0.06	-0.74	0.45	0.45	0.04	-6.3	-0.4	38.0	8.3	1.7	0.4	0.12	-0.22	-0.01	1.16	0.00	0.00
	10	0.15	-0.12	-0.71	0.43	0.64	0.09	-9.5	-0.8	49.4	11.4	2.7	0.8	0.28	-0.24	-0.01	1.17	0.00	0.00
	15	0.25	-0.21	-0.54	0.41	0.88	0.17	-13.7	-1.6	59.3	14.8	4.2	1.5	0.29	-0.23	-0.01	1.17	0.00	0.00
	20	0.34	-0.33	-0.23	0.41	1.16	0.28	-19.5	-3.3	69.2	19.4	7.1	3.0	0.34	-0.24	-0.01	1.17	0.00	0.00
7	5	-0.08	-0.04	-0.18	0.42	0.35	0.03	-4.3	-0.4	22.5	6.0	1.5	0.5	-0.34	-0.30	-0.01	1.16	0.01	0.00
	10	-0.03	-0.09	0.24	0.42	0.43	0.07	-5.3	-0.8	26.5	7.1	2.6	0.8	-0.22	-0.31	-0.00	1.16	0.01	0.00
	15	-0.01	-0.14	0.79	0.46	0.50	0.12	-6.4	-1.3	30.4	8.2	3.6	1.3	-0.12	-0.33	0.00	1.16	0.01	0.00
	20	-0.00	-0.21	1.40	0.52	0.57	0.18	-6.8	-2.5	32.2	8.7	5.4	2.4	-0.12	-0.33	0.01	1.17	0.01	0.00
8	5	-0.06	-0.02	-0.03	0.27	0.22	0.01	-1.8	-0.2	13.1	2.6	1.1	0.3	-0.91	-0.22	0.03	1.13	0.01	0.00
	10	-0.04	-0.03	-0.02	0.29	0.26	0.02	-2.0	-0.3	14.3	2.9	1.5	0.4	-0.88	-0.22	0.03	1.13	0.01	0.00
	15	-0.01	-0.05	0.00	0.28	0.30	0.04	-2.2	-0.5	15.2	3.1	1.8	0.5	-0.83	-0.23	0.03	1.14	0.01	0.00
	20	0.02	-0.07	0.04	0.27	0.35	0.06	-2.4	-0.6	15.7	3.2	2.2	0.6	-0.85	-0.23	0.03	1.14	0.01	0.00
9	5	-0.01	-0.06	-0.06	0.71	0.34	0.05	-7.8	-0.7	37.1	11.7	2.0	0.8	-0.53	-0.35	-0.01	1.16	0.00	0.00
	10	0.02	-0.13	0.90	0.87	0.43	0.10	-12.9	-1.6	44.7	16.2	3.4	1.6	-0.44	-0.37	-0.01	1.17	0.00	0.00
	15	-0.02	-0.26	1.81	1.02	0.61	0.21	-18.5	-3.6	47.6	20.2	6.0	3.4	-0.49	-0.40	-0.01	1.17	0.00	0.00
	20	-0.15	-0.48	3.06	1.28	0.85	0.39	-29.5	-4.4	57.9	28.6	6.6	4.3	-0.42	-0.43	-0.01	1.17	0.00	0.00

TABLE A(III)-45 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
10	5	-0.04	-0.04	-0.13	0.63	0.28	0.04	-5.0	-0.5	23.6	8.6	1.6	0.7	-1.63	-0.23	0.01	1.15	0.01	0.00
	10	-0.01	-0.09	0.07	0.71	0.39	0.08	-6.9	-1.0	28.2	10.6	2.3	1.2	-1.73	-0.23	0.01	1.15	0.01	0.00
	15	0.05	-0.17	0.37	0.75	0.50	0.16	-8.6	-2.2	30.4	12.1	3.6	2.1	-1.69	-0.25	0.00	1.16	0.01	0.00
	20	0.09	-0.30	0.69	0.81	0.66	0.27	-8.8	-4.7	29.1	11.8	6.4	4.5	-1.79	-0.25	-0.01	1.16	0.01	0.00
11	5	-0.04	-0.03	0.04	0.59	0.20	0.02	-3.1	-0.4	14.4	5.9	1.2	0.5	-1.24	-0.21	0.05	1.13	0.01	0.00
	10	-0.00	-0.06	0.04	0.64	0.26	0.05	-3.8	-0.7	16.5	6.8	1.6	0.8	-1.17	-0.22	0.05	1.13	0.01	0.00
	15	0.05	-0.10	0.11	0.69	0.32	0.09	-4.5	-1.1	18.0	7.4	2.2	1.2	-1.16	-0.23	0.05	1.14	0.01	0.00
	20	0.11	-0.16	0.22	0.71	0.39	0.14	-4.9	-1.9	18.8	7.8	2.9	1.9	-1.23	-0.22	0.05	1.14	0.01	0.00
12	5	-0.05	-0.02	-0.17	0.30	0.19	0.01	-1.8	-0.2	11.2	3.0	1.0	0.3	-0.80	-0.21	0.01	1.12	0.01	0.00
	10	-0.03	-0.03	-0.18	0.30	0.22	0.03	-2.1	-0.3	12.0	3.2	1.3	0.4	-0.82	-0.22	0.01	1.13	0.01	0.00
	15	0.00	-0.05	-0.17	0.31	0.25	0.04	-2.2	-0.5	12.7	3.4	1.6	0.5	-0.83	-0.22	0.01	1.13	0.01	0.00
	20	0.04	-0.07	-0.15	0.30	0.29	0.06	-2.4	-0.6	13.1	3.5	1.9	0.7	-0.80	-0.23	0.01	1.13	0.01	0.00
13	5	-0.07	-0.01	0.37	0.35	0.12	0.01	-1.5	-0.3	8.0	2.9	0.9	0.4	-2.71	-0.06	0.17	1.09	0.00	0.00
	10	-0.07	-0.03	0.42	0.38	0.14	0.03	-1.6	-0.4	8.6	3.1	1.2	0.5	-2.79	-0.06	0.18	1.10	0.00	0.00
	15	-0.05	-0.05	0.46	0.39	0.16	0.04	-1.8	-0.6	9.0	3.2	1.4	0.7	-2.83	-0.06	0.19	1.10	0.00	0.00
	20	-0.04	-0.07	0.48	0.40	0.19	0.06	-1.9	-0.7	9.4	3.3	1.6	0.8	-2.93	-0.06	0.19	1.11	0.00	0.00
14	5	-0.07	-0.02	0.55	0.35	0.11	0.02	-1.5	-0.3	7.9	3.0	0.9	0.4	-2.67	-0.03	0.25	1.09	-0.00	0.01
	10	-0.06	-0.03	0.60	0.38	0.13	0.03	-1.6	-0.4	8.4	3.1	1.2	0.6	-2.71	-0.02	0.26	1.10	-0.00	0.01
	15	-0.06	-0.05	0.62	0.40	0.15	0.05	-1.8	-0.6	8.7	3.2	1.4	0.7	-2.72	-0.02	0.27	1.10	-0.00	0.00
	20	-0.04	-0.07	0.66	0.41	0.18	0.07	-1.8	-0.8	9.0	3.3	1.7	0.9	-2.75	-0.02	0.27	1.11	-0.00	0.00
15	5	-0.05	-0.02	0.17	0.33	0.11	0.02	-1.4	-0.3	6.3	2.8	0.8	0.4	-2.03	-0.12	0.08	1.09	0.01	0.00
	10	-0.04	-0.03	0.18	0.35	0.13	0.03	-1.4	-0.4	6.6	2.8	1.1	0.6	-2.03	-0.12	0.09	1.09	0.00	0.00
	15	-0.02	-0.05	0.18	0.37	0.15	0.05	-1.3	-0.6	6.7	2.8	1.3	0.7	-1.97	-0.13	0.08	1.10	0.00	0.00
	20	0.00	-0.07	0.18	0.37	0.18	0.07	-1.1	-0.8	6.8	2.7	1.5	0.9	-2.01	-0.13	0.08	1.10	0.01	0.00
16	5	-0.06	-0.01	0.05	0.29	0.27	0.01	-1.5	-0.2	15.2	2.7	1.1	0.2	-0.45	-0.30	0.03	1.14	0.01	0.00
	10	-0.03	-0.03	0.14	0.29	0.30	0.02	-1.8	-0.3	16.7	2.9	1.4	0.3	-0.35	-0.31	0.03	1.14	0.01	0.00
	15	-0.01	-0.04	0.22	0.28	0.33	0.04	-2.1	-0.4	17.9	3.2	1.6	0.4	-0.36	-0.32	0.03	1.15	0.01	0.00
	20	0.01	-0.06	0.35	0.28	0.36	0.05	-2.3	-0.5	18.6	3.3	1.9	0.5	-0.40	-0.32	0.04	1.15	0.01	0.00
17	5	-0.11	-0.01	0.12	0.31	0.24	-0.00	-1.1	-0.2	12.6	1.9	1.1	0.2	-1.55	-0.30	0.07	1.13	0.01	0.00
	10	-0.09	-0.02	0.20	0.33	0.27	0.01	-1.2	-0.2	13.7	2.1	1.3	0.3	-1.32	-0.32	0.07	1.13	0.01	0.00
	15	-0.07	-0.03	0.30	0.33	0.29	0.02	-1.4	-0.3	14.4	2.2	1.6	0.3	-1.34	-0.33	0.07	1.14	0.01	0.00
	20	-0.06	-0.05	0.41	0.34	0.32	0.03	-1.6	-0.4	14.9	2.3	1.8	0.4	-1.39	-0.33	0.08	1.14	0.01	0.00
18	5	-0.09	-0.01	0.58	0.32	0.14	0.00	-1.2	-0.2	9.1	2.1	0.9	0.3	-2.33	-0.15	0.17	1.11	0.00	0.00
	10	-0.08	-0.02	0.65	0.35	0.15	0.01	-1.4	-0.3	9.7	2.3	1.1	0.3	-2.21	-0.16	0.17	1.11	0.00	0.00
	15	-0.07	-0.03	0.72	0.36	0.17	0.02	-1.5	-0.3	10.1	2.4	1.3	0.4	-2.24	-0.16	0.18	1.11	0.00	0.00
	20	-0.06	-0.05	0.80	0.37	0.18	0.04	-1.6	-0.4	10.4	2.4	1.5	0.4	-2.27	-0.16	0.19	1.12	0.00	0.00

TABLE A(III)-45 (CONT)

REGION		DISSOLVED N IN RUNOFF						DISSOLVED N IN PERCOLATION						DISSOLVED P IN RUNOFF					
	AW	A0	A1	A2	A3	A4	A5	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4	C5
19	5	-0.09	-0.01	0.76	0.39	0.12	0.01	-1.5	-0.3	9.2	2.7	0.9	0.3	-2.54	-0.06	0.24	1.10	-0.00	0.00
	10	-0.09	-0.03	0.85	0.43	0.13	0.02	-1.7	-0.4	9.8	2.9	1.2	0.4	-2.58	-0.06	0.25	1.11	-0.00	0.00
	15	-0.08	-0.04	0.93	0.45	0.15	0.03	-1.9	-0.5	10.3	3.0	1.3	0.5	-2.65	-0.05	0.26	1.11	-0.00	0.00
	20	-0.08	-0.06	0.98	0.47	0.17	0.05	-2.0	-0.6	10.6	3.1	1.5	0.6	-2.69	-0.05	0.26	1.12	-0.00	0.00
20	5	-0.07	-0.02	0.36	0.40	0.13	0.01	-1.6	-0.3	8.9	3.0	0.9	0.4	-1.91	-0.11	0.15	1.10	0.00	0.00
	10	-0.05	-0.03	0.41	0.43	0.16	0.02	-1.9	-0.4	9.4	3.2	1.2	0.5	-1.90	-0.12	0.15	1.11	0.00	0.00
	15	-0.03	-0.05	0.45	0.46	0.18	0.04	-2.0	-0.5	9.9	3.3	1.5	0.6	-1.90	-0.12	0.16	1.11	0.00	0.00
	20	-0.02	-0.07	0.50	0.48	0.21	0.05	-2.1	-0.7	10.4	3.4	1.7	0.8	-1.94	-0.12	0.16	1.12	0.00	0.00
21	5	-0.05	-0.02	0.27	0.34	0.12	0.02	-1.4	-0.3	7.5	2.8	0.9	0.4	-1.88	-0.10	0.13	1.10	0.00	0.00
	10	-0.04	-0.03	0.28	0.38	0.14	0.03	-1.5	-0.4	7.9	2.9	1.1	0.5	-1.88	-0.11	0.13	1.10	0.00	0.00
	15	-0.02	-0.05	0.29	0.41	0.17	0.04	-1.5	-0.5	8.2	3.0	1.4	0.6	-1.86	-0.11	0.13	1.11	0.00	0.00
	20	-0.00	-0.07	0.32	0.42	0.19	0.06	-1.5	-0.7	8.4	3.0	1.6	0.8	-1.86	-0.11	0.13	1.11	0.00	0.00
25	5	-0.07	-0.01	0.19	0.34	0.16	0.01	-1.3	-0.2	9.5	2.4	0.9	0.3	-1.98	-0.17	0.07	1.11	0.01	0.00
	10	-0.07	-0.02	0.23	0.36	0.18	0.02	-1.4	-0.3	10.1	2.5	1.2	0.4	-2.04	-0.16	0.07	1.12	0.01	0.00
	15	-0.07	-0.04	0.30	0.37	0.20	0.03	-1.5	-0.4	10.4	2.6	1.5	0.5	-2.12	-0.16	0.07	1.12	0.01	0.00
	20	-0.07	-0.05	0.37	0.38	0.22	0.04	-1.5	-0.5	10.6	2.7	1.7	0.6	-2.20	-0.15	0.07	1.12	0.01	0.00
26	5	-0.11	-0.02	0.00	0.37	0.12	0.01	-1.6	-0.3	8.0	3.1	0.9	0.4	-2.73	-0.10	0.02	1.10	0.00	0.00
	10	-0.11	-0.03	0.04	0.42	0.14	0.02	-1.8	-0.4	8.3	3.2	1.2	0.5	-2.72	-0.11	0.03	1.11	0.00	0.00
	15	-0.10	-0.05	0.07	0.45	0.16	0.04	-1.9	-0.6	8.2	3.2	1.5	0.7	-2.86	-0.10	0.03	1.11	0.00	0.00
	20	-0.08	-0.07	0.11	0.47	0.18	0.06	-1.9	-0.8	8.6	3.2	1.7	0.8	-3.00	-0.09	0.03	1.12	0.00	0.00
27	5	-0.07	-0.02	-0.06	0.36	0.13	0.03	-1.9	-0.4	9.1	4.2	1.0	0.5	-1.30	-0.25	0.00	1.12	0.00	0.00
	10	-0.04	-0.05	-0.06	0.39	0.17	0.05	-2.1	-0.6	9.3	4.4	1.5	0.8	-1.20	-0.25	0.00	1.13	0.00	0.00
	15	0.01	-0.08	-0.03	0.40	0.21	0.08	-2.2	-0.9	9.3	4.3	1.9	1.1	-1.14	-0.26	0.00	1.13	0.00	0.00
	20	0.06	-0.12	-0.01	0.40	0.27	0.12	-2.1	-1.2	9.9	4.2	2.0	1.4	-1.19	-0.26	-0.00	1.14	0.00	0.00

TABLE A(III)-46. CORN WITH WINTER COVER, NO TILLAGE (A,B,C,D SOILS)

REGION	AW	A	B	A'	B'	REGION	AW	A	B	A'	B'
1	5	1.56	-3.68	-1.45	35.40	13	5	3.29	-6.10	-3.24	67.65
	10	1.44	-3.47	-1.23	25.15		10	3.53	-6.56	-3.34	59.92
	15	1.41	-3.41	-1.10	20.40		15	3.66	-6.80	-3.34	56.39
	20	1.37	-3.30	-1.00	16.95		20	3.77	-7.02	-3.35	54.26
2	5	2.48	-5.33	-2.39	48.47	16	5	2.88	-5.99	-2.84	64.32
	10	2.41	-5.27	-2.15	38.40		10	2.92	-6.19	-2.77	57.57
	15	2.35	-5.17	-1.95	33.05		15	2.96	-6.29	-2.72	54.00
	20	2.28	-4.98	-1.83	29.36		20	3.00	-6.36	-2.71	51.67
6	5	1.62	-3.59	-1.50	34.28	17	5	3.06	-6.32	-3.01	64.89
	10	1.56	-3.63	-1.18	20.86		10	3.12	-6.67	-2.98	58.27
	15	1.46	-3.47	-0.93	15.04		15	3.15	-6.83	-2.94	54.68
	20	1.38	-3.31	-0.85	12.02		20	3.18	-6.88	-2.93	52.39
7	5	2.19	-4.69	-2.10	44.19	18	5	3.27	-6.66	-3.24	68.13
	10	2.21	-4.83	-1.88	30.13		10	3.42	-7.18	-3.32	62.53
	15	2.18	-4.91	-1.63	23.55		15	3.47	-7.37	-3.29	59.50
	20	2.14	-4.86	-1.42	19.47		20	3.52	-7.51	-3.29	57.51
8	5	3.01	-5.98	-2.96	62.22	19	5	3.07	-6.38	-3.02	64.44
	10	3.12	-6.38	-2.96	54.50		10	3.23	-6.84	-3.06	58.09
	15	3.19	-6.60	-2.94	50.63		15	3.32	-7.09	-3.06	55.16
	20	3.23	-6.72	-2.91	47.84		20	3.38	-7.26	-3.04	53.04
9	5	1.83	-3.92	-1.67	33.61	20	5	2.99	-5.97	-2.95	63.54
	10	1.67	-3.68	-1.15	17.05		10	3.22	-6.57	-3.05	55.85
	15	1.64	-3.65	-0.91	11.02		15	3.36	-6.93	-3.04	52.23
	20	1.57	-3.50	-0.61	7.11		20	3.44	-7.16	-3.00	49.94
10	5	2.16	-4.46	-2.05	42.34	22	5	3.16	-6.45	-3.14	69.16
	10	2.05	-4.22	-1.64	25.31		10	3.22	-6.79	-3.17	64.16
	15	1.99	-4.10	-1.38	17.65		15	3.25	-6.86	-3.20	62.10
	20	1.98	-3.99	-1.15	13.24		20	3.29	-7.04	-3.25	61.44
11	5	2.44	-5.05	-2.37	52.02	25	5	3.21	-6.56	-3.17	67.95
	10	2.44	-5.14	-2.16	38.58		10	3.38	-7.00	-3.29	61.18
	15	2.51	-5.36	-2.07	32.68		15	3.50	-7.33	-3.36	58.15
	20	2.55	-5.47	-1.99	29.52		20	3.57	-7.44	-3.35	55.97
12	5	2.96	-5.76	-2.92	62.98	26	5	3.18	-5.18	-3.15	61.90
	10	3.16	-6.27	-3.03	55.23		10	3.37	-5.73	-3.27	53.70
	15	3.27	-6.60	-3.01	51.75		15	3.49	-6.13	-3.34	50.73
	20	3.34	-6.86	-3.00	49.57		20	3.57	-6.28	-3.40	49.38

APPENDIX B

SEDIMENT AND NUTRIENT LOSS ESTIMATES FROM IRRIGATED AGRICULTURE

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Unlike the humid areas of the continental United States, methods and parameters for estimating soil erosion in the irrigated West are not well developed. Because of the diversity of crops, slopes, irrigation systems, and soils which exist, no attempt has been made in this report to provide generalized sediment and nutrient loss estimates for the entire region. Instead, a simple methodology for estimating losses is presented which provides a basis for comparing projected losses from different irrigated areas with or without changes in management. Where verification data are available, the report also pinpoints situations where current predictions are inadequate so that sediment and nutrient loss estimates can be refined as the data base and our knowledge of basic processes improves.

DETERMINING IRRIGATION REQUIREMENTS

Estimation of runoff and deep percolation water losses is essential to the prediction of sediment and nutrient losses from irrigated lands. A key parameter in this regard is the on-farm irrigation efficiency, which can be defined as the fraction of water applied to an irrigated field that is stored in the crop root zone. The remainder of the water is lost to evaporation, runoff, or deep percolation. In other words,

$$E = \frac{Q_a - Q_e - Q_r - Q_d}{Q_a} = \frac{Q_c}{Q_a}$$

where E = on-farm irrigation efficiency
Q_a = quantity of water applied
Q_e = quantity of water evaporated during application
Q_r = quantity of water which runs off
Q_d = quantity of water deep percolated
Q_c = quantity of water evapotranspired from the crop root zone (i.e., the net irrigation requirement).

Efficiency values are commonly expressed as percentages, but the fractional basis is more convenient for our purposes. This form of efficiency function differs from the overall system efficiency, which includes seepage losses from delivery canals, laterals, and on-farm ditches. Such losses, which are operationally difficult to distinguish from deep percolation, can be extremely important in terms of project-wide water requirements, localized groundwater accumulation, and salinity pickup (see Grand Valley Case Study, Planning Manual, Section V). Canal seepage losses are relatively unimportant with respect to sediment, phosphorus, or nitrogen pickup, however. Their main effect on nitrogen values, for example, is to dilute the nitrate concentrations of subsurface return flows from irrigated fields.

Values of Q_e usually range from 5 to 15 percent for sprinkler-irrigated fields. A level of 10 percent has been assumed for this report. Evaporative losses during application have been assumed negligible for furrow-irrigated fields. Evaporative losses from the surfaces of recently wetted (but empty) furrows are included in the Q_c values for a given crop and area. Values of Q_r are assumed negligible for sprinkler-irrigated fields, though localized runoff can be substantial when water is applied at high rates to soils of low intake capacity. A common example of such runoff can be observed near the periphery of center-pivot irrigation systems on fine-textured soils. It may contribute to localized differences in Q_d for such fields, due to water ponding as a result of the runoff. Values of Q_r are generally assumed to be more easily measured for furrow-irrigated fields than are values of Q_d, though this may not be true where well-designed subsurface drainage systems intercept virtually all deep percolation from an irrigated field without appreciable pickup of canal seepage or deep percolation from adjacent fields. In some cases, Q_d values can be estimated for sprinkler-irrigated fields as the difference between water applied and water calculated as evapotranspired by the growing crop. Still another method of estimating or cross-checking Q_d values, that of using parameters related to the uniformity and adequacy of irrigation, will be discussed later in this section.

On-farm irrigation efficiency is a concept widely used throughout the irrigated West. Efficiency estimates are commonly available for the major crops and irrigation systems of a given physiographic region. Validity of the estimates ranges from carefully-researched numbers to values which may be little more than educated guesses. Reliable values will depend upon crop, irrigation system, slope, soil depth, soil texture, set time, length of run, and irrigation stream size.

Rooting Zone, Depletable Moisture, and Number of Irrigations

The crop root zone can be defined as the depth of soil which is penetrated by crop roots. It may or may not include a limited depth of soil from which water is removed by upward flow into the actual root zone. Typical rooting depths for common irrigated crops range from 0.7 m (2 ft.) for peas, beans, and potatoes to 1.3 m (4 ft.) for irrigated alfalfa (USDA, 1973). Tabulated values generally assume that no obstructions to root growth are present, such as hard pans, chemically indurated layers, or dry soil.

Deep percolation is defined as that quantity of water which moves vertically through the soil below the crop root zone. Though subsequent upward movement is common under nonirrigated conditions, deep percolated water is normally unavailable for crop use in well-irrigated areas. The same would not be true where deficit irrigation is practiced.

Coarse-textured soils allow more rapid infiltration and percolation of water than do fine-textured (high-clay) soils. For this reason, coarse-textured soils have a larger potential for deep percolation, and fine-textured soils have a larger potential for surface runoff and erosion. Soils that are extremely coarse-textured may even result in such large percolation losses that furrow irrigation is no longer practical, so sprinkler irrigation must be used.

Fine-textured soils hold more water than do coarse-textured soils. Typical water holding capacities for major soil texture classes range from 0.08 cm/cm (1 inch/ft.) for sands to 0.3-0.4 cm/cm (4 inches/ft.) for clay loams (USDA, 1973). These water holding capacities are derived from "field capacity" measurements, with "field capacity" defined as the amount of water remaining in a soil 24 to 48 hours after a heavy irrigation under conditions of free drainage.

Depletable soil moisture can be defined as the quantity of moisture which may be withdrawn from the root zone without resultant crop moisture stress. At its maximum, it would be the water held between "field capacity" and the "permanent wilting point." At the permanent wilting point, however, soil water moves so slowly that it becomes insufficient to supply daily crop water requirements. For sustained economic crop production under irrigated conditions, only about one-half of the total moisture range should be regarded as truly depletable. Unacceptable moisture stress would result if the wilting point were approached prior to each irrigation.

Table B-1 presents depletable soil moisture values for major crops and soil types of the Magic Valley, Idaho, and the Umatilla Area, Oregon (see case studies A and E, Planning Manual, Section V). The values were computed using the relationship:

$$D = k(r)(w)$$

where D = depletable soil moisture in cm (inches)
k = a constant equal to 0.5 for all crops except potatoes, where it is set equal to 0.33
r = crop rooting depth in meters (feet)
w = soil water holding capacity in cm/meter (inches per foot).

Irrigation frequency and number of irrigations per season are determined by the time required for depletable moisture to be extracted from the crop root zone. Under ideal conditions, shallow-rooted crops or crops grown in coarse-textured soils would be irrigated more frequently than deep-rooted crops or crops grown in fine-textured soils. The relationship for determining number of irrigations (F) is:

$$F = Q_c/D$$

where Q_c = seasonal net irrigation requirement of the crop in cm (inches)
D = depletable soil moisture in cm (inches).

In practice, factors such as water needs by other crops on the same farm or in the same area, water availability, needs of water for wind erosion control or for promoting selective crop or weed emergence, individual preference for light irrigations versus heavy irrigations, and availability of irrigation labor are also important in determining irrigation frequency. Although scientific irrigation scheduling is becoming increasingly more common

TABLE B-1. ESTIMATED DEPLETABLE SOIL MOISTURE VALUES FOR MAJOR CROPS AND SOIL TYPES IN THE MAGIC VALLEY (IDAHO) AND UMATILLA (OREGON) AREAS (SEE CASE STUDIES D & E, PLANNING MANUAL, SECTION V)

Crop	Soil type Silt loam or loam	 Sandy loam	 Sand
	- - - - - - - - - - - cm	(inches) - - - - - - - - - - -	
Alfalfa	15.85 (6.24)	10.36 (4.08)	5.49 (2.16)
Small grains	11.89 (4.68)	7.77 (3.06)	4.11 (1.62)
Pasture	11.89 (4.68)	7.77 (3.06)	4.11 (1.62)
Peas	7.92 (3.12)	5.18 (2.04)	2.74 (1.08)
Field corn	13.87 (5.46)	9.07 (3.57)	4.80 (1.89)
Sugar beets	13.87 (5.46)	9.07 (3.57)	4.80 (1.89)
Dry beans	7.92 (3.12)	5.18 (2.04)	2.74 (1.08)
Potatoes	5.28 (2.08)	3.45 (1.36)	1.83 (0.72)

NOTE: Based on an assumption that 50 percent of soil water holding capacity is readily available for all crops except potatoes, for which the value is only 33 percent.

throughout the irrigated West, there remain considerable differences between growers as to when a given crop is judged ready for irrigation. At present, irrigation frequency generally remains a highly subjective determination.

Length of Set, Stream Size, and Length of Run

The time period over which water is continuously applied to the field by furrow or sprinkler (not including center-pivot) irrigation can be defined as the length of set. Coarse-textured soils or shallow-rooted crops normally require a shorter length of set (but more frequent irrigations) than do fine-textured soils or deep-rooted crops.

In practice, the length of set is determined as much by convenience as by exact field needs. The most common lengths of set are 12 or 24 hours, so that irrigation lines, or siphon tubes, can be changed at a specified time or times each day. A less common length of set, for fine-textured soils, deep-rooted crops, or sprinkler lines which apply water at uncommonly low rates, is 48 hours. For center-pivot systems, care is usually taken to ensure that a single revolution is completed in other than a 12-, 24-, 36-, or 48-hour period. This is done to prevent recurring application of water to a given part of the field at the same time each day. Less water remains in the root zone following mid-day irrigation (because of concurrent evaporation) than following irrigation at other times.

Stream size normally refers to the size of irrigation water stream delivered to the head of irrigation furrows. Because of infiltration along the furrow, it differs markedly from the size of stream flowing from the tail-end of that same furrow. Stream size is an important factor affecting furrow advance rate (the velocity at which the initial water stream moves down a previously dry furrow). A larger stream size results in a faster furrow advance rate at a given site, other factors remaining constant.

Fields with steeper slopes, finer-textured soils, or relatively smooth furrow surfaces all result in greater furrow advance rates. Conversely, recently tilled furrows result in slower furrow advance rates. A shorter period of furrow advance to the end of the field results in less deep percolation, since the head of the field is then being irrigated for a shorter time in relation to the total length of set. Hence, the uniformity of application is increased. A faster furrow advance rate also results in greater runoff, however. The optimal furrow advance rate is one which minimizes the sum of deep percolation and runoff losses. This is commonly established as the advance rate for which the total advance time is approximately one-fourth of the length of set (e.g., 5 to 7 hours for a 24-hour set). An alternative approach is to use cut-back irrigation, where a large stream size is used to push the stream through to the end of the furrow in minimal time, and then the stream size is cut back to minimize runoff and erosion.

The length of an irrigation furrow from top to bottom of the field is termed the length of run. The shorter the length of run, the shorter the furrow advance time, other factors remaining constant. Use of a shorter length of run also allows the use of a smaller stream size, which implies a slower furrow advance rate and reduced runoff losses. Hence, the use of a shorter length of run can reduce both deep percolation and runoff, and increase irrigation efficiency.

Coefficient of Uniformity and Adequacy of Irrigation

Any system of irrigation, whether it be furrow or sprinkler, results in nonuniform application of water over the field surface. In practice, for example, considerably more deep percolation occurs immediately beneath irrigation furrows than beneath adjacent crop rows, particularly on coarse-textured soils. In addition, the top portions of furrow-irrigated fields generally receive more water than do the bottom portions, producing greater deep percolation. Under sprinkler irrigation, overlapping sprinkler patterns result in double applications to some parts of the field, while other portions receive less than a full irrigation. Variations in sprinkler application uniformity are often described by the "coefficient of uniformity", with a value of 100 percent denoting completely uniform water application. Values for existing sprinkler systems are commonly in the range 60 to 80 percent. Though the concept is less commonly used for furrow-irrigated fields, uniformity coefficients in this case may be 50 to 60 percent or less. Improving the uniformity of water application results in a reduction in runoff and deep percolation losses, and increased irrigation efficiency.

The concept of "adequacy of irrigation" is not used extensively at present for irrigation water management in the West. With current emphasis on variability of water application and nutrient leaching, however, it is a concept which may be used with increasing frequency in the years ahead. The term can be defined as the percentage of the root zone throughout a field which is restored to field capacity during each irrigation. Obtaining an adequacy level of 100 percent is not possible at present without incurring substantial percolation losses. In order to meet crop water needs, most fields are irrigated to an adequacy level of 75 to 87.5 percent. The latter level is commonly cited in Water and Power Resources Services (U.S. Bureau of Reclamation) design criteria, but is rarely met in fields for which variations in water application are normally distributed. The value of the crop, the importance of uniform field appearance to the grower, and the availability of water and nutrients all interact to determine the appropriate adequacy level for a given irrigated setting.

Uniformity coefficient, adequacy level, and deep percolation (for normally-distributed variations in water application) are uniquely interrelated. If adequacy levels of 50 percent, 75 percent, and 87.5 percent are roughly equated to severely under-irrigated, "adequately" irrigated, and somewhat over-irrigated conditions, respectively, the interrelationship can be used as an alternative method of estimating deep percolation losses for nitrate leaching estimates.

In assigning a proper adequacy level, careful consideration should be given to portions of the field which are never irrigated to mid-row due to convex field ends or inadequate set times. Consideration should also be given to areas with reduced vegetative growth because of poorly designed or wind-distorted sprinkler patterns.

Irrigation Efficiency Estimates

Sample estimates of furrow irrigation efficiencies for major crops and alternative irrigation systems in the Magic Valley (Idaho) area are presented in Table B-2 (see Planning Manual, Case Study, Section V). The base for these estimates was the "improved management" efficiency estimates of Gossett (1975) for a comparable area of south central Washington. It was felt that the 10-year time span between Gossett's data base and recent studies (Obersinner 1979; McNeal, Whittlesey, and Obersinner 1980) warranted use of Gossett's "improved management" values over his "present management" estimates. Gossett's values also constituted a more complete data set than the data available from other sources (Whittlesey and Allison 1971; Kraft 1975; Fitzsimmons et al. 1978). Gossett's values represented approximately the mid-range of published estimates for the areas and crops in question.

TABLE B-2. ESTIMATED IRRIGATION EFFICIENCIES FOR MAJOR CROPS AND ALTERNATIVE IRRIGATION SYSTEMS IN THE MAGIC VALLEY (IDAHO) AREA

	Irrigation system*						
Crop	PFRW	IFRW	CTBK	PMPBK	GPIPE	MLTST	SDRL
	(percent)						
Alfalfa	57.5	62.5	72.5	77.1	77.5	92.5	75.0
Small grains	50.0	55.0	65.0	66.7	70.0	85.0	70.0
Pasture	50.0	55.0	65.0	67.6	70.0	85.0	70.0
Peas	47.5	52.5	62.5	62.7	67.5	82.5	62.5
Field corn	45.0	50.0	60.0	69.2	65.0	90.0	72.5
Sugar beets	45.0	50.0	60.0	69.2	65.0	90.0	72.5
Dry beans	37.5	42.5	52.5	57.0	57.5	82.5	62.5
Potatoes	32.5	37.5	47.5	50.0	52.5	77.5	60.0

NOTE: Assumes silt loam and loam soils with 0.5 percent to 2 percent slopes.

* PFRW - Present furrow system
IFRW - Improved furrow system
CTBK - Cutback irrigation system
PMPBK - Pump-back furrow system
GPIPE - Automatic gated pipe system
MLTST - Automatic multi-set system
SDRL - Side-roll sprinkler system

Having an estimate of efficiency also gives an estimate of total water loss. The difficulty comes in dividing losses between runoff and deep percolation. Runoff losses are at least measurable for verification purposes (though often not conveniently), so values of runoff will commonly be estimated and deep percolation will be taken as the remainder of the total loss value. Carter (personal communication) estimates that runoff values associated with furrow irrigation in the Magic Valley (Idaho) area are typically in the range of 30 to 40 percent, whereas Worstell (personal communication) estimates runoff values for the same area at 20 percent for close-growing crops and 30 percent for row crops. Based on these values, runoff estimates of 25 percent and 35 percent were used in this report for close-growing crops and row crops, respectively. Different values could be substituted for other areas, soil types, etc. With few exceptions, attempts will not be made to refine estimates of efficiency, runoff, or deep percolation to closer than ± 5 percent, because of the uncertainties of existing data.

Runoff estimates were next deducted from irrigation efficiency estimates (expressed as percentages) to give estimates of deep percolation. Deep percolation should increase, however, as crop rooting depth decreases. It was necessary to slightly adjust some of the efficiency values in order to yield this desired relationship with crop rooting depth, while still keeping the efficiency estimates within the overall range of values reported by Gossett. The efficiency estimates were adjusted instead of the runoff values since more confidence was felt in the latter. Resultant runoff and deep percolation values for the Magic Valley (Idaho) area are given in the first column of Table B-3.

Efficiency values for an "improved" furrow (IFRW) system were obtained from the base-level values by adding 5 percent to each furrow efficiency estimate in order to arrive at a corresponding value for an "improved" furrow system. It was assumed that the decrease in losses was divided evenly between runoff and deep percolation.

Efficiency values for the cutback (CTBK) system were estimated in the same manner, with a 15 percent increase in efficiency over the base level efficiency being assumed. Two-thirds (10 percent) of the increase was attributed to decreased runoff losses, and 5 percent was attributed to decreased deep percolation.

Changes in efficiency and losses for the gated pipe (GPIPE) system were assumed to be the sum of those for the improved furrow and cutback systems, since the gated pipe system has features of each. Therefore, the irrigation efficiency, runoff, and deep percolation estimates for this system were changed by 20 percent, 12.5 percent, and 7.5 percent, respectively.

For the multi-set (MLTST) irrigation system, according to Worstell (1976), irrigation efficiencies above 90 percent are possible. In order to achieve at least this level for several crops, 35 percent and 45 percent were added to the efficiency values of the present furrow system for close-growing and row crops, respectively. Runoff losses for multi-set systems were estimated to be 5 percent of the water applied, with deep percolation assumed to account for the remainder of the losses.

Gossett (1975) used U.S. Bureau of Reclamation data from central Washington to derive estimates of efficiencies for various crops when using side-roll sprinkler systems. Between-crop variations arose primarily from differences in crop rooting depth. Published efficiency estimates for side-roll systems range from 65 to 75 percent, which is close to Gossett's range of 59.3 to 74.7 percent. On this basis, Gossett's estimates for a well-managed side-roll system were used in this report. Runoff losses from sprinkler-irrigated fields were assumed to be zero, and 10 percent of the applied water was assumed to be lost as spray evaporation and wind drift. Deep percolation was estimated by deducting wind and evaporation losses from total losses for the sprinkler systems.

TABLE B-3. ESTIMATED PERCENT RUNOFF AND DEEP PERCOLATION FOR MAJOR CROPS AND ALTERNATIVE IRRIGATION SYSTEMS IN THE MAGIC VALLEY (IDAHO) AREA

	Irrigation system*						
Crop	PFRW	IFRW	CTBK	PMPBK	GPIPE	MLTST	SDRL
	Runoff (%)						
Row	35.0	32.5	25.0	0.0	22.5	5.0	0.0
Close-growing	25.0	22.5	15.0	0.0	12.5	5.0	0.0
	Percolation (%)						
Alfalfa	17.5	15.0	12.5	22.9	10.0	2.5	15.0
Small grains	25.0	22.5	20.0	33.3	17.5	10.0	20.0
Pasture	25.0	22.5	20.0	33.3	17.5	10.0	20.0
Peas	27.5	25.0	22.5	37.3	20.0	12.5	27.5
Field corn	20.0	17.5	15.0	30.8	12.5	5.0	17.5
Sugar beets	20.0	17.5	15.0	30.8	12.5	5.0	17.5
Dry beans	27.5	25.0	22.5	43.0	20.0	12.5	27.5
Potatoes	32.5	30.0	27.5	50.0	25.0	17.5	30.0

NOTE: Assumes silt loam and loam soils with 0.5 percent to 2 percent slopes.

* PFRW - Present furrow system
IFRW - Improved furrow system
CTBK - Cutback irrigation system
PMPBK - Pump-back furrow system
GPIPE - Automatic gated pipe system
MLTST - Automatic multi-set system
SDRL - Side-roll sprinkler system

The range in estimated efficiency values for center-pivot systems is commonly from 75 to 85 percent, with a large number of estimates concentrated in the range from 80 to 82 percent. On this basis, an efficiency value of 80 percent was used for present center-pivot systems in the Pacific Northwest. Field runoff was assumed to be zero for such systems, with spray evaporation and wind losses assumed equal to 10 percent. The remainder of the losses (i.e., 10 percent) were attributed to deep percolation.

Shearer (1978) indicated a variance of 7 percent in center-pivot system efficiencies, part of which is due to differences in management. Busch (1978) gave a range of 3 percent for center-pivot efficiencies, reflecting differences in management. An intermediate value of 5 percent was assumed for the improvement in efficiency as improved management techniques are applied to center-pivot systems. Spray evaporation and wind losses were assumed to remain unchanged.

The discerning reader will have noted an inconsistency between the technique used for assigning irrigation efficiencies to the side-roll and the center-pivot sprinkler systems. In one case, crop-specific differences (largely due to differences in crop rooting depth) were introduced; in the other, they were not. One or the other of these approaches should be adopted consistently by personnel of a given planning group. In the absence of definitive data, center-pivot irrigation efficiencies could be assumed to vary from 85% (for alfalfa) to 75% or 70% (for potatoes), by arranging the crops in the relative order of efficiencies listed for side-roll systems (Table B-3).

Effect of Texture and Slope on Irrigation Efficiency

Since various soil textures exist throughout the irrigated West, it is necessary to have some feeling for the effects of texture on efficiency, runoff, and deep percolation.

Gossett's (1975) estimates of furrow irrigation efficiencies show negative adjustments (i.e., greater losses) for more coarse-textured soils. This is because his efficiency values were calculated as a positive linear function of depletable soil moisture, which decreases for coarse-textured soils. However, Gossett's adjustments do not include texture-dependent variations in infiltration rate or runoff losses. Runoff losses decrease for coarse-textured soils, which tends to offset the increase in deep percolation. Apparently, the Hagen (1978) efficiency estimates (based on data from California) and the USDA (1973) estimates (based on data from central Washington) already took into consideration these offsetting trends, for no adjustment in irrigation efficiency with soil texture was proposed. Since it is felt that the increase in deep percolation tends to be greater than the decrease in runoff as soils become more coarse-textured, however, a negative adjustment in efficiency of 5 percent was used in this report as the dominant soil texture was changed from silt loam to sandy loam.

Hence, all efficiency values for base-level (silt loam) soils of the case study area were reduced by 5 percent in order to obtain corresponding irrigation efficiency values for sandy loams. The deep percolation values for silt loams or loams were also adjusted upward by 5 percent in order to obtain corresponding values for sandy loams. No soil-texture dependent adjustment of runoff losses was required, though the sandy loam soils were treated as less erosive per unit of runoff volume than their silt loam counterparts.

Estimating the effects of field slope on irrigation efficiency, runoff, and deep percolation is also important. Published values suggest that efficiencies of both furrow and sprinkler systems generally decrease as slope increases, though sprinkler system efficiencies often do not vary until after the slope has been increased by 5 to 10 percent. The trend toward decreased efficiencies is probably due to an increased probability of runoff from steeper slopes.

Control of furrow stream size is more difficult on steeper slopes, and the grower tends to be generous in the stream size allocated, so the percent runoff tends to increase. The stream tends to run down the furrow more rapidly on steeper slopes, however, resulting in a smaller wetted cross section. This should operate to decrease deep percolation, and may in some cases approximately balance the increased runoff. For this report, furrow irrigation efficiency was assumed to remain unchanged in going from a 0.5-2.0 percent slope class to a 2-5 percent slope class. Likewise, no adjustment in efficiency is generally required for sprinkler irrigation systems experiencing this same change in slope class. Therefore, efficiency values for the 0-2 percent slope class were assumed to remain valid for slopes of 2-5 percent in all cases. However, the runoff and deep percolation values for the base-level (0-2 percent slope class) conditions were respectively increased by 5 percent and decreased by 5 percent for furrow irrigation systems on slopes of 2-5 percent.

Net Irrigation Requirements

Crop consumptive use is defined as the amount of water transpired during plant growth plus that evaporated from the soil surface and foliage of the area occupied by the growing plant (Sutter and Corey, 1970). The net irrigation requirement is commonly defined as crop consumptive use less seasonal precipitation (Watts et al., 1968). It does not consider moisture stored in the root zone at the beginning of the growing season. As a result, estimates of net irrigation requirement somewhat overstate seasonal crop needs for irrigation water, especially if "deficit" irrigation (using previously stored soil moisture) is to be practiced. Despite this, net irrigation requirement estimates are commonly used, because other appropriate water-use data are limited.

Net irrigation requirements are often based upon a modified Blaney-Criddle procedure, which considers mean daily temperature, hours of daylight, and crop characteristics. Estimates commonly reflect mean seasonal net irrigation requirements, requirements for the eighth driest year out of ten, or maximum net irrigation requirements for the period of record.

According to Wright (personal communication), the Blaney-Criddle method underestimates crop consumptive needs because the formula underestimates evaporation. Such underestimation occurs because differences in elevation are not considered in the approach (with more evaporation occurring at higher elevations) and also because the method uses mean daily temperatures, whereas daytime temperatures alone tend to determine the amount of evaporation.

Our study made use of Wright's irrigation requirement estimates for alfalfa, spring grain, peas, and dry beans (Table B-4). As Wright did not at the time have estimates for other crops of the Magic Valley (Idaho) study area, Blaney-Criddle maximum estimates for the period of record were used since they were closest to Wright's estimates for the above four crops (Sutter

TABLE B-4. SEASONAL NET IRRIGATION REQUIREMENTS FOR MAJOR CROPS IN THE MAGIC VALLEY (IDAHO) AND THE UMATILLA (OREGON) AREAS

Crop	Magic Valley	Umatilla
	ha-cm/ha (acre-inches/acre)	
Alfalfa	94 (37)	104 (41)
Spring grain	56 (22)	-- (--)
Winter grain	64 (25)	64 (25)
Pasture	64 (25)	-- (--)
Peas	41 (16)	-- (--)
Field corn	56 (22)	74 (29)
Sugar beets	74 (29)	-- (--)
Dry beans	51 (20)	53 (21)
Early potatoes	-- (--)	71 (28)
Late potatoes	66 (26)	94 (37)

and Corey 1970). For the Umatilla area (Oregon) study area, Vomocil's (1976) irrigation requirement estimates were chosen to represent the best currently available values for the area. They are Blaney-Criddle estimates for the eight driest years out of ten.

Estimates of Water Application Requirements

Once estimates are available for the quantity of water to be applied and for the percent runoff and deep percolation, it is possible to obtain estimates of the amount of runoff and the amount of deep percolation by simply multiplying the appropriate terms together. Estimated seasonal water application requirements for major crops and alternative irrigation systems in the Magic Valley (Idaho) and Umatilla (Oregon) areas are presented in Tables B-5 and B-6.

To estimate efficiency, deep percolation, and water application requirement values for pump-back (PMPBK) irrigation systems (which were not dealt with earlier in this section), quantities of deep percolation (Q_d) were assumed to be equivalent to those for the present furrow system. These

TABLE B-5. ESTIMATED SEASONAL WATER APPLICATION REQUIREMENTS FOR MAJOR CROPS AND ALTERNATIVE IRRIGATION SYSTEMS IN THE MAGIC VALLEY (IDAHO) AREA

Crop	Irrigation system*						
	PFRW	IFRW	CTBK	PMPBK	GPIPE	MLTST	SDRL
	ha-cm/ha (acre-inches/acre)						
Alfalfa	163 (64)	150 (59)	130 (51)	122 (48)	122 (48)	102 (40)	124 (49)
Spring grain	112 (44)	102 (40)	86 (34)	84 (33)	81 (32)	66 (26)	81 (32)
Winter grain	127 (50)	117 (46)	99 (39)	95 (37.5)	91 (36)	76 (30)	91 (36)
Pasture	127 (50)	117 (46)	99 (39)	95 (37.5)	91 (36)	76 (30)	91 (36)
Peas	86 (34)	79 (31)	66 (26)	65 (25.5)	61 (24)	51 (20)	66 (26)
Field corn	124 (49)	112 (44)	94 (37)	81 (31.8)	86 (34)	61 (24)	76 (30)
Sugar beets	163 (64)	145 (57)	122 (48)	106 (41.6)	112 (44)	81 (32)	102 (40)
Dry beans	137 (54)	119 (47)	97 (38)	89 (35.1)	89 (35)	61 (24)	81 (32)
Late potatoes	203 (80)	175 (69)	140 (55)	132 (52)	127 (50)	84 (33)	109 (43)

NOTE: Assumes silt loam and loam soils with 0.5 percent to 2 percent slopes.

* PFRW - Present furrow system
IFRW - Improved furrow system
CTBK - Cutback irrigation system
PMPBK - Pump-back furrow system
GPIPE - Automatic gated pipe system
MLTST - Automatic multi-set system
SDRL - Side-roll sprinkler system

TABLE B-6. ESTIMATED SEASONAL WATER APPLICATION REQUIREMENTS FOR MAJOR CROPS AND THE CENTER-PIVOT

Crop	Irrigation system PCP	 ICP
	- - ha-cm/ha (acre-inches/acre) - -	
Alfalfa	130 (51)	122 (48)
Winter grain	79 (31)	76 (30)
Field corn	91 (36)	86 (34)
Dry beans	66 (26)	61 (24)
Early potatoes	89 (35)	84 (33)
Late potatoes	117 (46)	112 (44)

NOTE: Assumes sandy soils.

estimates were added to net irrigation requirement (Q_c) values in order to obtain water requirement values (Q_a) for the pump-back system. Hence,

$$Q_a = Q_c + Q_d$$

Efficiency values for the pump-back system (E) were then obtained as

$$E = Q_c/Q_a$$

Values for percent deep percolation from the pump-back system (P) were obtained as

$$P = 100 - E,$$

because field runoff for the pump-back system was assumed equal to zero.

II. SEDIMENT AND PHOSPHORUS LOSSES

Most phosphorus lost from irrigated croplands is associated with eroding sediment. Hence, this section will dwell in greatest detail on factors affecting sediment erosion.

Base-level conditions have been assumed as follows: potatoes grown on a silt-loam soil at 1.5 percent slope, employing an 8 gallon per minute stream size (at the head ditch), and producing 35 percent runoff for a 24-hour irrigation set. This combination of conditions is assumed to yield approximately 40 metric tons per hectare of sediment loss for the season, with 8.2 mt per ha lost during each of the first 3 irrigations, 2.7 mt per ha lost during the next 5 irrigations, and 0.4 mt per ha lost during each of the final 5 irrigations. Phosphorus losses have been estimated at 0.14% of sediment losses. Changes in sediment loss are then based upon changes from base-level conditions. Changes in sediment:phosphorus ratios will be necessary as the approach is applied to other furrow-irrigated areas.

Slope and Stream-Size Effects

The relation of stream size and furrow slope to soil erosion was examined by Gardner and Lauritzen (1946), Israelson et al. (1946), Evans and Jensen (1952), and Mech (1959). Gardner and Lauritzen (1946) attempted to derive equations for determining minimal erosive stream sizes for various furrow slopes on silt loam soils. Israelson et al. (1946) claimed that erosion increased as the square of the slope (i.e., as $(\text{slope})^2$) for a silty clay loam, with a less marked dependence (as $(\text{slope})^{1.5}$) for a sandy loam and a more marked dependence (as $(\text{slope})^{2.7}$) for a sand. Fitzsimmons et al. (1978) found that erosional losses from a bean field in southern Idaho corresponded to a dependence on $(\text{slope})^{2.1}$ to $(\text{slope})^{3.4}$. The relations all seemed to fluctuate around $(\text{slope})^2$, and averaged $(\text{slope})^{2.2}$ for the above cases. So that a false sense of accuracy (and hence authenticity) was not placed on the relation adopted, a dependence of erosion on $(\text{slope})^2$ was assumed for this report. Subsequently, the base sediment loss would be adjusted by a factor equal to $(\%\ \text{slope})^2/(1.5)^2$, which is the ratio of the square of the actual slope to the square of the base-level slope (Table B-7).

Evans and Jensen (1952) formulated an equation relating soil erosion to the product of $(\text{slope})^{2.3}$ and $(\text{runoff})^{1.5}$. In the Boise Valley of Idaho, Fitzsimmons et al. (1978) reported that doubling the stream size (but maintaining the same amount of water applied) approximately doubled both the amounts of surface runoff and sediment loss. This would generally be an unrealistic approach, however, for irrigation is usually carried out for a specified set time (often 24 hours) rather than for a specified quantity of applied water. Doubling both the stream size and the total amount of water applied increased sediment losses four-fold in this same study (i.e., sediment loss depended on $(\text{stream size})^{2.0}$ under more normal operating conditions). Fitzsimmons et al. (1978) also reported sediment yields in the Magic Valley of Idaho for another set of conditions which would correspond to an erosion dependence on $(\text{runoff volume or stream size})^{3.6}$. For still another study site, Fitzsimmons et al. (1978) reported an erosion dependence on $(\text{runoff})^{1.65}$. There is obviously a considerable spread in erosion dependence on stream size or runoff volume. The above exponents average 2.3. As with the previous treatment of slope/erosion interactions, to avoid the conferring of a false sense of accuracy, a dependence on $(\text{stream size or runoff volume})^{2.0}$ has been assumed for the purposes of this report. Appropriate multipliers are listed in Table B-8.

TABLE B-7. MULTIPLIERS TO BASE-LEVEL IRRIGATED SEDIMENT LOSS VALUES TO ADJUST FOR FIELD SLOPE

Slope (%)	Multiplier
0.25	0.03
0.50	0.11
1.00	0.44
1.50	1.00
2.50	2.80
3.50	5.40
5.00	11.00
8.00	28.00

TABLE B-8. MULTIPLIERS TO BASE-LEVEL IRRIGATED SEDIMENT LOSS VALUES TO ADJUST FOR RUNOFF VOLUME

Slope (%)	Multiplier
40	1.30
35	1.00
30	0.73
25	0.51
20	0.33
15	0.18
10	0.08
5	0.02

Tillage and Set-Time Effects

The relation of freshly disturbed furrows (Evans and Jensen 1952) to increased erosional losses has been demonstrated experimentally. Greater than ten-fold decreases in erosion were noted by Mech and Smith (1967) between initial and subsequent irrigations following reditching operations. Similarly, Fitzsimmons et al. (1978) reported that over one-third of the seasonal sediment loss occurred during a single preplant irrigation, and that loss from a seed corn field (which was cultivated several times) was over 50-fold the loss from an alfalfa field (which was cultivated very little). These workers also reported greater erosional losses if furrows were compacted than if not, though poor water distribution and excessive deep percolation generally occurred if the furrows were not compacted. Brown et al. (1974) reported sharply reduced erosional losses after weeding and refurrowing of row crops was stopped in the Magic Valley area of southern Idaho. Unfortunately, cultivation between irrigations is often necessary to break surface crusts and to maintain adequate water intake rates. To account for tillage effects on erosion losses from irrigated fields, the approach of Gossett (1975) has been used for this report. Gossett assumed that erosion losses for each of the first three irrigations of a potato field in the Yakima Valley of Washington were three times (300 percent of) the losses from each of the next five (mid-season) irrigations, because of tillage preceding each early season irrigation. He assumed that sediment losses during each of five late-season irrigations were only 15 percent of those during each mid-season irrigation. This approach requires adjustment if a given crop has more, or fewer, irrigations following tillage operations than assumed by Gossett. For a wheat crop, for example, only one "early season" irrigation (i.e., following a tillage operation) might be assumed, with remaining irrigations then assigned to the "mid-season" and "late-season" modes. As more sophisticated surface-irrigation methods are adopted, use of cutback techniques may also be adopted for early-season irrigation to minimize tillage effects.

Mech (1959) also reported that 78 percent of the total sediment lost from a section of recently cultivated furrows during a 24-hour irrigation was lost during the first 32 minutes of runoff, and that virtually all of the eroded sediment was lost during the first 4 hours of irrigation. This was true even though flow slowly increased with time because of decreasing water intake rate. Carter and Bondurant (1977) claimed that less erosion should occur from fields that were irrigated longer and less frequently, though such an approach might increase leaching losses and could be impractical for shallow-rooted crops. Consistent irrigators tend to produce a "peak" in sediment loss during each irrigation set (Mech 1959), by having many furrow streams reach the end of the row at similar times. Research in the Yakima Valley (L.G. King, personal communication) has shown, however, that flows from different furrows tend to arrive at the tail ditch at different times under common irrigation conditions. No set-length dependence of erosion losses has been assumed for this report, so a relatively constant distribution of sediment losses with time during any given irrigation is inherent to our approach. A set-length dependence of erosion losses remains a necessary refinement in many situations.

Soil-Texture Effects

Soil texture is another important variable affecting sediment losses from irrigated lands. Pfeiffer (1976) incorporated soil-texture effects through the use of soil erodibility ("K") factors from the Universal Soil Loss Equation (USLE). Appropriate "K" values were obtained for our studies from nomographs in the Stewart et al. (1975) report. Inputs included: percent silt plus very fine sand, and percent sand (these values were taken from the midpoint of an SCS textural triangle for each soil textural class); soil organic matter content (a value of 1 percent was assumed to typify the arid conditions under which most irrigated lands of the West have developed); soil structural clss (assumed medium to coarse granular); and soil permability class (assumed "moderate"). Resultant "K" values were 0.48 for silt loams, 0.28 for loams, 0.22 for silty clays, 0.18 for sandy loams, and 0.09 for loamy sands. These values are assumed proportional to sediment loss for the respective soil types. Since the base soil condition was given as silt loam, the adjustment factors would be as listed in Table B-9.

Workers for the SCS have developed "K" values for many actual soil series, based upon more precise soil texture, organic matter, structure and permeability information. These values will generally be within 0.05 of the values listed above, however, and relative values will often be in virtually exact agreement. Refinements may eventually be necessary, for silt loams in the Yakima Valley are reportedly less erosive than silt loams in the Twin Falls area (D.C. Larsen, personal communication). Soil-series-specific "K" factors may help in this regard.

Crop Effects

Crop type is yet another important variable affecting soil erosional losses. Gossett (1975) reported relative sediment losses from row crops, as

TABLE B-9. MULTIPLIERS TO BASE-LEVEL IRRIGATED SEDIMENT LOSS VALUES TO ADJUST FOR SOIL TEXTURE

Soil Texture	Multiplier
Silt loam	1.00
Loam	0.79
Sandy loam	0.53
Silty clay	0.34
Loamy sand	0.30

compared to close growing-crops, of three- to ten-fold. Fitzsimmons et al. (1978) reported that a bean field with slope only one-half that of a seed corn field still had three times the erosional losses. After the slope change is accounted for as outlined earlier, this would correspond to roughly a twelve-fold difference in erosional losses between the two crops. Based upon data generated by Fitzsimmons et al. (1978), and with consideration of the concept of "limited accuracy" that applies to such data, potatoes have been assigned an average sediment loss value of 40 mt/ha (18 tons/acre) under base-level conditions. Similarly, other row crops have been assigned a sediment loss value 40 percent as large (16 mt/ha or 7.2 tons/acre) and close-growing crops have been assigned a sediment loss value only 5 percent as large (2 mt/ha or .9 tons/acre). These multipliers are listed in Table B-10.

The extreme variations with crop type reflect in part localized differences in management practices. For example, Rasmussen (personal communication) has observed farmers applying up to 30 cm (12 inches) of water to wet an entire crop field in a single, preplant irrigation for beans. This practice would produce extremely large amounts of erosion from the unprotected and recently-tilled soil. Similarly, erosion often virtually ceases for many row crops once plant leaves or stems have begun to accumulate in the irrigation furrows. Such debris essentially creates a series of check dams, or "mini sediment basins," down the length of the furrow.

The high erosion losses from furrow-irrigated potatoes will likely decrease as more growers convert to sprinkler systems. It has been estimated, for example, that 85 to 90 percent of the potatoes in Idaho are now sprinkler-irrigated (D.C. Larsen, personal communication).

Phosphorus Losses

Loss of total phosphorus is generally correlated with sediment loss, since much of the phosphorus is attached to eroding particles. Fitzsimmons et al. (1978), for example, found a correlation coefficient of 0.8 between total P and suspended solids. No apparent relation exists between soluble orthophosphate and sediment concentrations (Carter et al. 1976), however.

TABLE B-10. MULTIPLIERS TO BASE-LEVEL IRRIGATED SEDIMENT LOSS VALUES TO ADJUST FOR CROP TYPE

Crop type	Multiplier
Potatoes	1.00
Other row crops	0.40
Close-growing crops	0.05

Greater amounts of phosphorus appear to be associated with a given weight of fine sediments (e.g., clay and silt-sized) than with the same weight of coarse sediments (e.g., sand-sized). Also, finer sediments are less likely to settle out in ponds or retention basins. Carter et al. (1974) reported that retention basins removing 65 to 75 percent of the sediment from runoff water removed only 55 to 65 percent of the total P, and Fitzsimmons et al. (1978) found phosphorus-removal levels of only 35 to 78 percent for sediment ponds removing 82 to 91 percent of the runoff water sediments.

Carter et al. (1974) summarized a large number of sediment and phosphorus loss data for two of the main irrigated tracts of the Magic Valley. Total phosphorus loss in their studies averaged 0.14 percent of total sediment loss, or 1.4 Kg of total phosphorus per tonne of eroded sediment (2.8 lbs/ton).

This method of estimating phosphorus loss ignores differences in fertilization rates between crops. Presently, adequate data are simply not available to allow such a distinction. Similarly, no attempt has been made in this report to subdivide eroded phosphorus into soluble, "available" (extractable), or nonextractable forms, because of the poor correlation reported by Carter et al. (1974) when such attempts were made.

Sample Predictions

Sample sediment loss predictions for the Magic Valley (Idaho) area are presented in Table B-11. These values have been used for the case studies. reported in Section V of the planning manual.

Verification of Sediment Loss Estimates

Data with which to verify the sediment loss model are limited at best. Although agreement was reasonably good between predicted values and values obtained from southern Idaho and from the Columbia Basin (Fitzsimmons et al., 1978; McNeal et al., 1979), this comparison provides only a limited degree of independent verification since the Fitzsimmons et al. (1978) data were a major part of the data base used to develop the predictive model. Unpublished data presented by D.L. Carter at the 1979 meetings of the American Society of Agronomy provided a better opportunity to verify the predictive model. Comparison of Carter's data with predicted values produced a slope of .61 and a correlation coefficient (r value) of 0.993. Omitting the field from which sediment loss was the greatest, because of its dominance of regression relationships, a slope of 0.73 and an r value of 0.941 resulted. There remains considerable room for improvement in the sediment loss estimates, but they seem to be of proper magnitude and well correlated with measured values.

III. NITROGEN LOSSES

Most nitrogen loss from irrigated croplands is associated with deep percolation. Unless soluble nitrogen has been metered into the irrigation water, the levels of soluble nitrogen in surface runoff are essentially equal to the levels in the corresponding irrigation water. Small but measurable amounts of total nitrogen are also associated with eroding sediments, due to

TABLE B-11. ESTIMATED SEDIMENT LOSS FOR MAJOR CROP TYPES AND ALTERNATIVE IRRIGATION SYSTEMS IN THE MAGIC VALLEY (IDAHO) AREA

Crop type	Irrigation system* PFRW	IFRW	CTBK	PMPBK or SDRL	GPIPE	MLTST
	- - - - - - - - - - - - - -		mt/ha (tons/acre)		- - - - - - - - - - - - - -	
Potatoes	40.4(18.0)	34.5(15.4)	20.6(9.2)	0(0)	16.6(7.4)	0.78(0.35)
Other row crops	16.1(7.2)	13.9(6.2)	8.3(3.7)	0(0)	6.5(2.9)	0.31(0.14)
Close-growing crops	1.03(0.46)	0.83(0.37)	0.36(0.16)	0(0)	0.25(0.11)	0.04(0.02)

NOTE: Assumes silt loam soils with 1.5 percent slopes.

* PFRW - Present furrow system
IFRW - Improved furrow system
CTBK - Cutback irrigation system
PMPBK - Pump-back furrow system
GPIPE - Automatic gated pipe system
MLTST - Automatic multi-set system
SDRL - Side-roll sprinkler system

sediment organic matter and exchangeable ammonium contents and associated crop residues. In humid and subhumid regions (which are generally ignored in this section of the report), amounts of total nitrogen in eroding sediments may be appreciable due to higher soil organic matter contents.

The quantity of nitrate leached below the root zone (and hence unavailable for crop use) is dependent both upon the volumes and the nitrogen concentrations of the drainage waters (Adriano et al., 1972a; Ayers and Branson, 1973). Limiting nitrate losses from soils may therefore be approached in two ways: (1) by reducing the volumes of drainage water, and/or (2) by reducing the nitrate concentrations of those waters.

Nitrogen Budgets

In a controlled situation, the amount of nitrogen added to irrigated soils each season is reasonably well known. Fertilizer inputs, and inputs with the irrigation water, are a matter of record. Biological nitrogen fixation can be estimated from published work with the crops in a given crop rotation, or from ethylene reduction assays. In much of the arid West, where little native soil organic matter is present, net mineralization is a minor contributor to the nitrogen balance and can often be assumed equal to zero. Denitrification (conversion to gaseous forms such as N_2 or N_2O), however, is not so easily determined. Most attempts to quantify denitrification in the field have used a nitrogen budget, attributing to denitrification that portion of the total nitrogen losses not accounted for by other mechanisms (crop removal, leaching, residual soil nitrogen, etc.). If the goal is to limit the amount of nitrate leached below the crop root zone, the goal is most practically attained by reducing the amount of nitrogen applied, increasing the amount of denitrification occurring, or reducing the quantity of leaching water.

Project-Wide Studies

Nelson and Weaver (1971) studied the salt balance for a 28,400 ha (70,000 acre) subunit in the Wapato Irrigation Project in central Washington, with results compared to those from a similar study during 1941-42. Prior to the mid-1940s, fertility was maintained with manures and with crop rotations, including legumes. By 1970, however, most fertilization was through the use of commercial fertilizers. During the 29 years between studies, alfalfa acreage was cut by 76 percent, with increased acreage being planted to crops such as spearmint, peppermint, hops, sugar beets, and corn. Outputs of nitrate had increased five-fold by 1970-71, with increased use of fertilizer nitrogen thought to be the primary factor increasing the nitrate contents of drainage water from the area. Cropping changes may also have contributed materially to the trends, however. Another factor which may have accounted for some of the differences is the presence or absence of aquatic weeds. Such weeds can remove substantial quantities of nitrogen from the water-return system, and were more effectively controlled in 1970-71.

Bingham et al. (1971) investigated nitrate-nitrogen (NO_3-N) leaching losses for a 390 ha (970 acre) watershed cropped to citrus in southern California. An average of 45 percent of the applied water was leached below the crop root zone, with nitrate-nitrogen levels of the drainage waters corresponding to an average of 64 Kg N/ha/yr (57 lbs. N/acre/yr.). Noncultivated lands produced an average of less than one-fourth as much nitrate.

Carter et al. (1971) calculated the salt balance for a 81,000 ha (200,000 acre) irrigated tract on the Snake River Plains of southern Idaho. They noted an annual leaching loss of 34 Kg N/ha (30 lbs. N/acre) of irrigated land. Fertilizer company records for the area indicated that nitrogen fertilization rates had averaged only about 60 Kg N/ha/yr (54 lbs. N/acre/year) in this tract, but half or more of the leached nitrogen may have arisen from alfalfa plowout, rather than from commercial fertilizer application.

Individual-Field Studies

Adriano et al. (1972a) investigated a 7-year nitrogen balance for asparagus grown on a sandy soil. They noted that NO_3-N concentrations of drainage waters were higher at higher fertilization rates and lower irrigation levels (though actual NO_3-N loadings generally decreased with decreased irrigation rate). Denitrification was assumed to have caused greater quantities of unaccounted-for nitrogen at higher irrigation rates. Adriano et al. (1972b) found little evidence of denitrification at sites characterized by open, porous soil. At sites with restricted layers in the upper portion of the profile, on the other hand, drainage water nitrogen concentrations estimated from a mass-balance equation (based on nitrogen applied, nitrogen used by the crop, and depth of drainage water) were overestimated by as much as 56 percent. At a site where animal manures were used as the main nitrogen source, estimated NO_3-N concentrations were overestimated by as much as 73 percent. Appreciable denitrification appparently occurred in each of these cases.

Pratt et al. (1972) stated that accurate estimates of NO_3-N concentrations could be made if the following parameters were known: (1) excess nitrogen available for leaching; (2) volume of drainage water; and (3) the amount of denitrification occurring. For a sandy loam soil with no textural discontinuities (e.g., silt or clay lenses which impede downward water movement), this approach closely estimated the NO_3-N concentrations of unsaturated soil below the crop root zone. For two nearby commercial citrus groves, where the soil contained a high clay horizon at 45 to 100 cm (18 to 40 inches), fully 50 percent of the applied nitrogen could not be accounted for by this approach. It was assumed denitrified. Unfortunately, textural discontinuities appear to be the rule, rather than the exception, throughout much of the irrigated West.

Lund et al. (1974) found that the texture of the "profile control section" (that zone most thoroughly controlling the rate of water movement through the profile) influenced both the volume and the NO_3-N concentrations of drainage waters. The greater the clay content of the control section, the lower the NO_3-N concentrations on the soil solution. This is probably a direct effect on denitrification losses. Devitt et al. (1976) used changes in the Cl/NO_3 - ratio with depth below the root zone as an indicator of denitrification, in situations were Cl was not taken up by the crop. Lund and Elliot (1976) sampled sites having variable profile characteristics within a single field, and found that the Cl/NO_3 ratio correlated highly with the particle size distribution of the soil control section. Pratt et al. (1976) found a nearly linear correlation between the saturated hydraulic conductivity of the 0 to 1 m (0 to 3 foot) section of the profile and unaccounted-for nitrogen, which was presumed to have been denitrified.

Earlier Nitrate Leaching Estimates

One of the most comprehensive early attempts to provide nitrate leaching estimates for a variety of cropping and irrigation conditions was undertaken by Regional Technical Committee W-111 ("Nitrogen and the Environment") in 1973. Members of this committee from throughout the western states were asked to provide estimates of leaching losses at five nitrogen fertilization rates for well-drained and poorly-drained soils at low, medium, and high degrees of leaching. Crops characterized included irrigated pasture, wheat, alfalfa, potatoes, and apples. Most committee members assumed that crops removed 50 to 60 percent of the applied nitrogen, and that 10 to 30 percent of the applied nitrogen was denitrified. Thus, 10 to 40 percent of the applied nitrogen would be lost to percolating waters. Most committee members assumed that only small losses would be incurred from alfalfa as a living crop, although losses may be substantial after the crop is plowed under. Most appear to assumed that crop requirements for nitrogen were met before either percolation or denitrification occurred.

Nitrogen loss estimates for irrigated pasture and alfalfa were generally less than 6 to 11 Kg/ha (5 to 10 lbs/acre). The low leaching estimates were largely a consequence of the low fertilization rates assumed for these crops. Substantially higher leaching losses were estimated for small grains, potatoes, and apples. Values commonly exceeded 28 to 56 Kg/ha (25 to 50 lbs/acre) at the intermediate and highest leaching fractions and nitrogen application rates. A value in excess of 112 Kg/ha (100 lbs/acre) was estimated for potatoes under conditions of greatest nitrogen leaching. Corresponding values for poorly-drained soil were only about half as high, both because of lower leaching fractions and because of the greater potential assumed for denitrification.

Gossett (1975) developed a regression equation describing nitrate leaching data generated by Pratt and co-workers in California. This equation has been tested subsequently on a wide variety of southern California data, and found to quite accurately predict nitrate leaching losses for that area. The relation has the form:

$$N_L = 0.22\ (NiD)^{0.712}$$

where N_L = nitrate leaching losses in kg N/ha/yr
Ni = nitrogen inputs in kg/ha/yr
D = drainage water volume in ha-cm/ha/yr

There is generally poor agreement between nitrate leaching values estimated from Gossett's equation and those estimated by members of the W-111 Regional Committee, with leaching estimates from the regression equation consistently the higher of the two. One explanation for this discrepancy might be that the

California crops for which the equation was developed were weighted towards heavily fertilized vegetable crops and towards well-managed (and hence frugally-irrigated) crops, whereas the Regional Committee estimates were weighted towards less intensively-managed crops. Another explanation might be that the Regional Committee members were overly conservative in their estimates.

Nitrogen Fertilizer Recommendations

In obtaining estimates of nitrogen leaching for irrigated portions of the West, it is necessary to input probable nitrogen application rates for a wide range of crop and soil settings. Nitrogen fertilization recommendations can be obtained from fertilizer guides published by the Agricultural Experiment Stations of the several western states. It should be recognized, however, that the actual fertilizer application may differ substantially from fertilizer guide recommendations. At present in the Pacific Northwest, for example, there appears to be a consistent tendency to exceed fertilizer guide nitrogen application rates in irrigated areas, as a form of "insurance" on high crop yields and because fertilizer guides are often viewed by growers as oriented towards "average" (rather than high-level) producers.

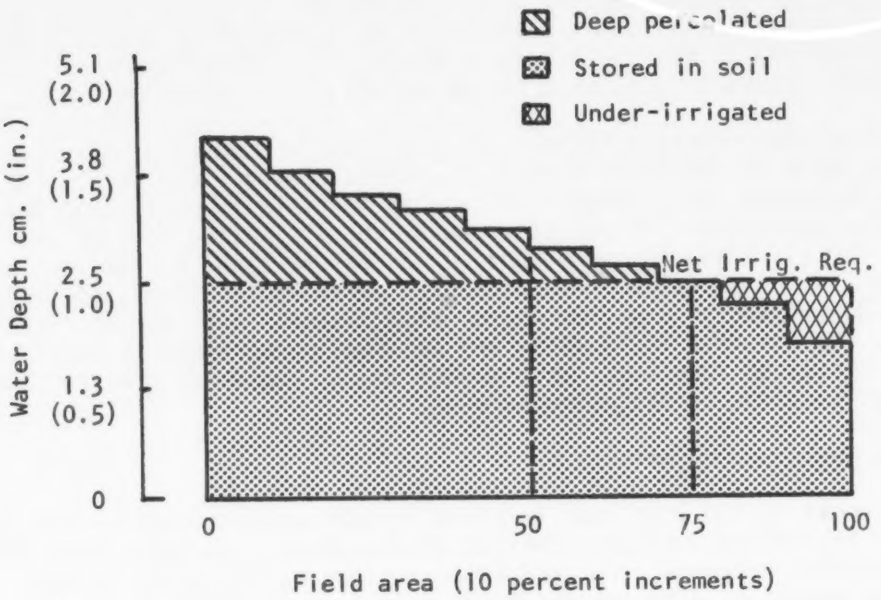
Estimating Deep Percolation Losses

In addition to nitrogen fertilization rates, some estimate of the quantity of water which deep percolates is required for nitrate leaching estimates. Several methods of estimating deep percolation losses can be employed. The recommended approach for this report consists of estimating deep percolation (as a percentage of the water application to a given field) as 100 percent minus both the on-farm irrigation efficiency (expressed as a percentage) and the percent runoff (for furrow-irrigated fields) or evaporative losses during application (for sprinkler-irrigated fields). Estimation of each of these parameters was dealt with in considerable detail earlier.

For some irrigation systems, deep percolation estimates can be obtained from estimates of uniformity coefficient and adequacy level. A typical water distribution is shown in Figure B-1, assuming a normal distribution of variations in water application. A field net irrigation requirement of 2.54 cm (1 inch), a uniformity coefficient of 80 percent, and a 75 percent adequacy level is shown (i.e., three-fourths of the root zone soil is returned to maximum water holding capacity during an average irrigation). Most subunits in the field (shown as 10 percent increments or 0.1 field subunits in the figure) must be over-irrigated to meet this adequacy level. As a result deep percolation occurs, and the tradeoff between under-irrigation and deep percolation is readily apparent. As less and less of the field's root zone area is under-irrigated, by increasing the amount of water applied, more and more of the field is subjected to excessive deep percolation. Such deep percolation carries soluble nutrients, particularly nitrates.

Despite difficulties in its measurement, the adequacy level can at least be qualitatively or semi-quantitatively estimated (as described earlier in this section), in order to provide nitrate leaching estimates under selected

Figure B-1. Water distribution.



field conditions. Such estimation, though crude, is still of approximately the same degree of accuracy as many of the other types of estimates available for irrigated croplands.

For furrow-irrigation systems the uniformity coefficient is commonly unknown, at least with our present state of knowledge. Estimates of percent deep percolation can be made by subtracting the percent runoff and the percent efficiency from 100. If the resultant deep percolation loss corresponds to an unrealistic uniformity coefficient, then either a different adequacy level or a different on-farm efficiency may be required to "fine tune" the deep percolation and uniformity coefficient estimates.

Deep percolation estimates can be obtained for subunits of an irrigated field, as well as for the entire field, if water application is assumed to be normally distributed. Our studies have made use of ten subunits, each consisting of 10 percent of the field's area. The exact location of each subunit within the field is not specified, but such an assignment is generally not necessary. Crop appearance and/or yield may serve as a useful guide to locations of excessive leaching where necessary. By assigning an adequacy level and a uniformity coefficient, or by knowing one of these values and the field-wide percentage of deep percolation,

it is possible to estimate the amount of deep percolation or underirrigation for each field subunit. Table B-12 shows caluculated values of subunit deep percolation for various uniformity coefficients at three adequacy levels (the data relate equally to sprinkler- or furrow-irrigated settings). The deep percolation values are expressed as a percent of the average amount of water applied to the field. As a result, it is possible to have deep percolation losses of greater than 100 percent for a given subunit.

For furrow-irrigated fields, one would expect ridges of the crop row and the lower part of the field (especially where convex field ends occur because of prior erosion) to correspond in general to field subunits that are not adequately irrigated. On the other hand, the irrigation furrows and the upper part of the field should correspond in general to subunits that are over-irrigated. For sprinkler irrigation, the water application pattern is non-uniform due to design problems and/or wind distortion of the application pattern. No specific field locations can thus be assigned to underirrigated or over-irrigated subunits. Crop growth and/or yield may provide clues to such distribution, as discussed earlier.

Nitrogen Leaching Estimates

Nitrogen in the root zone is often assumed proportional to the amount of nitrogen fertilizer applied. Several studies have also shown that excessive irrigation can decrease crop production, with a major factor in such decreases being the amount of nitrogen which has been leached (Middleton and Roberts 1972; Kloster and Whittlesey 1971). As mentioned earlier, Gossett (1975) analyzed much data generated during extensive studies of nitrate leaching by workers from the University of California. He fit the data to an equation of the form:

$$N_L = 0.22\ (N_f Q_d)^{0.712}$$

where N_L = nitrate leaching losses in kg N/ha/year
N_f = fertilizer nitrogen inputs in kg N/ha/year
Q_d = drainage water volume in ha-cm/ha/year

This equation fit the University of California field data with an r^2 value of 0.908.

The slope of the above curve does not stand up to close scrutiny, for it predicts relatively less leaching of fertilizer nitrogen as either the drainage water volume or the nitrogen fertilization rate is increased. The former is as anticipated, for there is only a finite quantity of nitrogen present to be leached. Most studies, however, have found increasing proportions of fertilizer nitrogen leached as the fertilization rate is increased, rather than the converse. As a result, Pfeiffer (1976) used the following equation to estimate nitrogen leaching, based upon the same data:

$$N_L = 0.032\ (N_f)^{1.05}\ (Q_d)^{0.7}$$

TABLE B-12. PERCENT DEEP PERCOLATION FOR THE ENTIRE FIELD AND FOR TENTH-FIELD SUBUNITS AT SELECTED UNIFORMITY COEFFICIENTS AND AND ADEQUACY LEVELS

		Field subunit a/									
Unformity coefficient	Entire field	1	2	3	4	5	6	7	8	9	10
(%)					50% adequacy level						
100	-	-	-	-	-	-	-	-	-	-	-
95	2.5	10.5	6.5	4.5	2.5	0.8	-	-	-	-	-
90	5	21	13	9	5	1.5	-	-	-	-	-
85	7.5	32	19.5	13	7.5	2.3	-	-	-	-	-
80	10	43	26	17	10	3	-	-	-	-	-
75	12.5	54	32.5	21	12.5	4	-	-	-	-	-
70	15	65	39	25	15	5	-	-	-	-	-
65	17.5	76	45.5	29.5	17	5.5	-	-	-	-	-
60	20	87	52	34	19	6	-	-	-	-	-
55	22.5	98.5	59	38.5	21.5	7	-	-	-	-	-
50	25	110	66	43	24	8	-	-	-	-	-
45	27.5	121	72.5	47	26.5	9	-	-	-	-	-
40	30	132	79	51	29	10	-	-	-	-	-
					75% adequacy level						
100	-	-	-	-	-	-	-	-	-	-	-
95	5	15	11	8.5	6.5	5	3.5	2	-	-	-
90	10	30	22	17	13	10	7	4	-	-	-
85	15.5	45	32.5	25.5	20	15	10.5	5.5	-	-	-
80	21	60	43	34	27	20	14	7	-	-	-
75	26	75.5	54	42.5	33.5	25	17.5	9	-	-	-
70	30	91	65	51	40	30	21	11	-	-	-
65	36	106	75.5	59.5	46.5	35	24.5	13	-	-	-
60	41	121	86	68	53	40	28	15	-	-	-
55	46	137	97	76.5	60	45	31.5	16.5	-	-	-
50	52	153	108	85	67	50	35	18	-	-	-
45	58	168	119	93.5	73.5	55	38	20	-	-	-
40	62	183	130	102	80	60	41	22	-	-	-
					87.5% adequacy level						
100	-	-	-	-	-	-	-	-	-	-	-
95	7	17	13	11	9	7.5	6	4	2.5	-	-
90	14	34	26	22	18	15	12	8	5	-	-
85	21	17.5	39	32.5	27	22	17.5	12.5	7	-	-
80	28	69	52	43	36	29	23	17	9	-	-
75	35	86.5	65.5	54	45	36.5	29	21	11.5	-	-
70	42	104	79	65	54	44	35	25	14	-	-
65	49	121.5	94	75.5	63	51.5	40.5	29	16.5	-	-
60	56	139	105	86	72	59	46	33	19	-	-
55	63	157	118	97	81	66	52	37	21	-	-
50	70	175	131	108	90	73	58	41	23	-	-
45	77	193	144	119	99	80.5	63.5	45.5	25.5	-	-
40	84	211	157	130	108	88	69	50	28	-	-

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a/ Each field subunit is defined as 10 percent of the field's area. Deep percolation for subunits 9 and 10 equals zero for all uniformity coefficients and adequacy levels listed. Percent deep percolation for each subunit is defined as a percent of the overall water application requirement.

This relation is more consistent with observed nitrate loss patterns than is Gossett's.

Because of the less efficient furrow irrigation systems in general usage throughout much of the Pacific Northwest, compared to the more efficient irrigation sytems (often sprinkler systems) at many of the University of California study sites, direct use either of Gossett's or or Pfeiffer's equation in this report generally resulted in over-estimation of nitrogen leaching losses. McNeal and Pratt (1978), for example, found nitrate leaching predictions from these equations to be two- to three-fold too high for the Twin Falls (Carter et al., 1973) and Wapato (Nelson and Weaver, 1971) irrigation projects. It was, therefore, deemed advisable to make field subunit adjustments before applying Pfeiffer's equation, and to provide an upper limit for the amount of nitrogen that could be leached from each subunit no matter how much water passed through that portion of the field.

Deep percolation estimates for individual one-tenth field subunits were used in our studies, along with a modified Pfeiffer equation, to obtain nitrogen leaching estimates for each subunit rather than for the field as a whole. These values were then summed to obtain field-wide values. The equation used to obtain subunit leaching values had the form:

$$N_L = 0.038 (N_f)^{1.05} (Q_d)^{0.7}$$

The first two columns of data in Table B-13 present the individual subunit deep percolation values required to obtain a total field-wide deep percolation value of 20.54 percent (corresponding to a 75 percent adequacy level and an 80 percent uniformity coefficient) at a total water application rate of 127 cm (50 inches). The next column presents the fertilizer application rate per tenth-field subunit if the fertilizer were uniformly applied, and the following column provides corresponding nitrogen leaching estimates. Each of the latter values was obtained through use of the adjusted Pfeiffer equation. The net result of the subunit approach was only a 10 percent reduction in the nitrate leaching estimate (39.9 kg N/ha or 35.6 lbs N/acre) when compared to the value obtained from fieldwide use of the Pfeiffer equation (43.9 kg N/ha or 39.2 lbs N/acre).

When furrow irrigation is simulated, leaching of nitrogen can be more accurately described by assuming that the most heavily leached subunits of each field are associated with the irrigation furrows. For illustrative purposes it might be assumed that only one-tenth as much of any band-applied fertilizer nitrogen ends up in the most heavily leached subunit (e.g., within the irrigation furrow) and that only one-half as much fertilizer nitrogen ends up in the next most heavily leached subunit. For the remainder of the field, the fertilizer application would then be 1.175 times the average fertilization rate, so that the total quantity of nitrogen applied per acre remained unchanged. The final columns of Table B-13 shows these subunit fertilization rates and resultant nitrate leaching values. The leaching values are reduced approximately 20 percent further, to approximately two thirds of the original field-wide Pfeiffer estimates. The leaching estimates for the most heavily leached and next most heavily leached subunits are substantially reduced by this "simulated furrow" technique. Hence, additional

TABLE B-13. DEEP PERCOLATION, NITROGEN FERTILIZER APPLICATION, AND NITRATE LEACHING FOR TENTH-FIELD SUBUNITS OF A FURROW-IRRIGATED FIELD (SAMPLE CASE)

	Deep Percolation		Subunit Leaching Technique		Simulated Furrow Leaching Technique	
Field subunit	Percent a/	Quantity b/ cm (inches)	Nitrogen Fertilizer Application c/ kg (pounds)	Nitrate Leaching kg (pounds)	Nitrogen Fertilizer Application c/ kg (pounds)	Nitrate Leaching kg (pounds)
1	60	76.2(30)	4.5(10)	3.9(8.7)	.5(1.0)	.35(0.78)
2	43	54.6(21.5)	4.5(10)	3.2(7.0)	2.3(5.0)	1.5(3.4)
3	34	43.2(17.0)	4.5(10)	2.7(5.9)	5.3(11.75)	3.2(7.0)
4	27	34.3(13.5)	4.5(10)	2.2(4.9)	5.3(11.75)	2.7(5.9)
5	20	25.4(10)	4.5(10)	1.8(4.0)	5.3(11.75)	2.2(4.9)
6	14	17.8(7)	4.5(10)	1.5(3.2)	5.3(11.75)	1.7(3.7)
7	7	8.9(3.5)	4.5(10)	.9(1.9)	5.3(11.75)	1.0(2.3)
8	0	0(0)	4.5(10)	0(0)	5.3(11.75)	0(0)
9	0	0(0)	4.5(10)	0(0)	5.3(11.75)	0(0)
10	0	0(0)	4.5(10)	0(0)	5.3(11.75)	0(0)
Field-wide average	20.54	26.1(10.27)	45.4(100)	16.2(35.6)	45.4(100)	12.7(27.9)

a/ Assumes an adequacy level of 75 percent and a uniformity coefficient of 80 percent.

b/ Assumes a water application requirement of 127 cm (50 inches).

c/ Assumes a nitrogen fertilization rate of 45.4 kg (100 pounds) per acre.

water which might pass through the soil beneath the furrows would have little effect on nitrate leaching, despite its considerable influence on Pfeiffer's field-wide estimates. The difference between nitrate leaching estimates from the field-wide and "simulated furrow" estimation techniques would be even larger for larger nitrogen fertilizer application rates or water application requirements.

Leaching estimates obtained from the "simulated furrow" leaching technique are probably more representative of nitrogen leached from furrow-irrigated fields of the Pacific Northwest than are the directly applied field-wide values. For sprinkler irrigation, estimates from the subunit leaching technique are also probably more useful than directly-applied field-wide values. Though the sprinkler irrigation estimates could be improved somewhat further by adjusting the amount of fertilizer nitrogen in each subunit to correspond with either band or broadcast application of fertilizer, the only reasonable approximation at present is to assume a uniform distribution of fertilizer nitrogen throughout each field subunit.

Denitrification Corrections

Water-saturated surface soils provide the best conditions for gaseous loss of nitrogen via denitrification, for they have both the microbes and the energy source (soluble or solid-phase carbon) required for the process. Relatively high soil temperatures also speed the conversion.

Estimates of nitrogen leaching using the techniques described above all assume an amount of denitrification roughly equivalent to that from a uniform sandy loam under southern California conditions. For other soil types, Pratt (1979) has shown that adjustments can be made in the form of multipliers (m) based on saturated soil hydraulic conductivity (h) values using the equation:

$$m = 0.8(h)^{0.5}$$

Multipliers for specific surface-soil textures are listed in Table B-14. It appears that approximate multipliers may also be attainable from the relation m = (0.015)(percent sand) for additional soil types.

As an example, assume that the value of nitrate leaching under simulated furrow leaching (31.3 kg/ha or 27.9 lb/acre) in Table B-13 was for a uniform sandy loam. Using the appropriate denitrification multiplier for silt loams (0.4), we obtain

$$27.9(0.4) = 12.5 \text{ kg/ha } (11.2 \text{ lbs/acre})$$

The estimate of nitrate leaching is now only approximately 30 percent of the value obtained using the unmodified Pfeiffer equation (43.9 kg/ha or 39.2 lbs/acre). Approximately 30 percent of the decrease is due to adoption of the "simulated furrow" leaching technique, and another 40 percent is due to use of the denitrification multiplier. The net effect is values which are much more in agreement with nitrate leaching values for Pacific Northwest irrigated tracts (Nelson and Weaver 1971; Carter et al. 1973; McNeal and Pratt 1978) than were the unmodified Pfeiffer estimates.

TABLE B-14. NITRATE LEACHING DENITRIFICATION MULTIPLIERS FOR SELECTED SATURATED HYDRAULIC CONDUCTIVITY VALUES AND CORRESPONDING SOIL TEXTURES

Soil texture	Saturated hydraulic conductivity	Multiplier
	cm/hr (inches/hr)	
Coarse sand	10 (4.0)	1.6
Sandy loam	4.1 (1.6)	1.0
Silt loam	0.5 (0.2)	0.4
Silty clay loam	0.08 (0.03)	0.15

NOTE: These multipliers are to be applied to the nitrate leaching values for sandy loam soils in order to obtain estimates for other soil textures.

Sample Predictions

Sample nitrate leaching predictions for the Magic Valley (Idaho) and Umatilla (Oregon) areas are presented in Tables B-15 and B-16. These values are used for the case studies reported in the planning manual, Section V.

IV. GEOGRAPHICAL DIFFERENCES IN THE IRRIGATED AGRICULTURE PREDICTIONS

The preceding estimates of sediment and phosphorus loss from irrigated fields were derived mainly from sediment-loss measurements in Idaho, Washington, and Utah, coupled with irrigation efficiency measurements in California, Washington, and Idaho. Nitrate leaching estimates were based primarily on data from extensive studies in central and southern California, as modified to more accurately describe irrigated settings in Washington and southern Idaho. The major case study areas used for economic evaluations of sediment and nutrient loss control measures are located in south central Washington, south central Idaho, and north central Idaho.

The techniques described can be applied as well to center-pivot irrigated fields in the Sand Hills of Nebraska, to furrow-irrigated fields in eastern Colorado, or to basin-irrigated fields in central Arizona. The authors are currently assembling published information from throughout the irrigated West for model verification and/or refinement purposes. The models of sediment and phosphorus runoff losses, and of nitrate leaching losses, at least provide a basis for comparison so that situations which are inadequately described can be recognized and dealt with subsequently.

TABLE B-15. NITROGEN APPLICATION RATES AND ESTIMATED LEACHING LOSSES FOR MAJOR CROPS AND ALTERNATIVE IRRIGATION SYSTEMS IN THE MAGIC VALLEY(IDAHO) AREA

Crop	PFRW	IFRW	CTBK	PMPBK	GPIPE	MLTST	SDRL
- - - - - Nitrogen application rate, kg/ha or (pounds/acre) a/ - - - - -							
Alfalfa	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Spring grain	113(101)	111(99)	108(96)	113(101)	106(95)	104(93)	111(99)
Winter grain	113(101)	111(99)	108(96)	113(101)	106(95)	103(92)	110(98)
Pasture	113(101)	111(99)	108(96)	113(101)	106(95)	103(92)	110(98)
Peas	40(36)	39(35)	39(35)	40(36)	38(34)	37(33)	40(36)
Field corn	226(202)	216(202)	213(190)	226(202)	208(186)	199(178)	215(192)
Sugar beets	197(176)	192(171)	189(169)	197(176)	185(165)	176(157)	190(170)
Dry beans	35(31)	34(30)	32(29)	35(31)	32(29)	31(28)	35(31)
Potatoes	248(221)	237(212)	227(203)	248(221)	222(198)	207(185)	234(209)
- - - - - Nitrate leaching loss, kg/ha or (pounds/acre) - - - - -							
Alfalfa	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Spring grain	13.7(12.2)	11.6(10.4)	8.5(7.6)	13.7(12.2)	8.0(7.1)	4.6(4.1)	11.4(10.2)
Winter grain	15.0(13.4)	12.8(11.4)	10.2(9.1)	15.0(13.4)	8.6(7.7)	4.9(4.4)	12.3(11.0)
Pasture	15.0(13.4)	12.8(11.4)	10.2(9.1)	15.0(13.4)	8.6(7.7)	4.9(4.4)	12.3(11.0)
Peas	4.1(3.7)	3.6(3.2)	2.9(2.6)	4.1(3.7)	2.5(2.2)	1.6(1.4)	4.3(3.8)
Field corn	31.5(28.1)	20.9(18.7)	18.1(16.2)	31.5(28.1)	14.1(12.6)	5.4(4.8)	20.2(18.0)
Sugar beets	27.1(24.2)	22.4(20.0)	19.2(17.1)	27.1(24.2)	14.9(13.3)	5.6(5.0)	21.5(19.2)
Dry beans	4.7(4.2)	3.9(3.5)	3.1(2.8)	4.7(4.2)	2.7(2.4)	1.5(1.3)	4.3(3.8)
Potatoes	56.9(50.8)	46.6(41.6)	35.4(31.6)	56.9(50.8)	30.1(26.9)	15.1(13.6)	41.2(36.8)

NOTE: Assumes silt loam soils with 0.5 percent to 2 percent slopes.
a/ 1 pound/acre = 1.12 kg/hectare.

* PFRW - Present furrow system
IFRW - Improved furrow system
CTBK - Cutback irrigation system
PMPBK - Pump-back furrow system
GPIPE - Automatic gated pipe system
MLTST - Automatic multi-set system
SDRL - Side-roll sprinkler system

TABLE B-16. NITROGEN APPLICATION RATES AND ESTIMATED NITRATE LEACHING LOSSES FOR MAJOR CROPS UNDER THE CENTER-PIVOT IRRIGATION SYSTEMS IN THE UMATILLA (OREGON) AREA

	Nitrogen Application Rate		Nitrate Leaching Loss	
Crop	PCP*	ICP**	PCP	ICP
	- - - - - - - - -	kg/ha (pounds/acre) a/	- - - - - - - - -	
Alfalfa hay	0(0)	0(0)	0(0)	0(0)
Winter grain	180(161)	157(140)	46.5(41.5)	23.7(21.2)
Field corn	226(202)	194(173)	64.5(57.6)	32.5(29.0)
Dry beans	169(151)	151(135)	38.1(34.0)	19.8(17.7)
Early potatoes	338(302)	290(259)	97.1(86.7)	49.3(44.0)
Late potatoes	451(403)	368(329)	159.9(142.8)	76.2(68.0)

NOTE: Assumes sandy soils.
a/ 1 pound/acre = 1.12 kg/ha.

* PCP - Present center-pivot.
** ICP - Improved center-pivot.

The models have been kept simple intentionally, while still incorporating the most important physical parameters and processes conceptualized to date, so that they may be used with minimum difficulty by planning groups and by research workers from outside the physical and biological sciences. The far-western bias of the data base used for model development and initial verification is acknowledged. It is no more provincial, however, than the strong mid-western bias of initial sediment loss estimates for nonirrigated regions (i.e., development of the Universal Soil Loss Equation). In each case, only a few locations have undertaken the extremely expensive and time consuming research needed for model verification and refinement, so climatic and physiographic settings near or similar to those where the most research has been conducted enjoy greatest initial emphasis as the new models emerge.

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APPENDIX C

ESTIMATING THE COST-EFFECTIVENESS OF SALINITY CONTROL MEASURES

W. R. Walker and T. E. Waddell

SECTION 1

INTRODUCTION

BACKGROUND

Salinity is among the most serious water quality problems associated with irrigated agriculture. As water is diverted from rivers, streams reservoirs, and groundwater basins for agricultural needs, the salts in the water are concentrated by evapotranspiration. If they are not leached from the crop root zone, the productive capacity of the land will be eliminated. On the other hand, if the flow of water through the root zone greatly exceeds the natural drainage capacity of underlying soils and aquifers, the water table level may rise until salts are transported into the root zone by the upward movements of water caused by evapotranspiration. Thus, salinity is a potentially significant problem in every agricultural area being irrigated.

Salinity problems also have a regional scope. A downstream user is generally supplied a more saline water than an upstream neighbor because the concentrating effect, as well as the increased mass of salts acquired through physical and chemical weathering of soil and acquifer materials. Salinity levels in the lower elevations of a watershed reach their highest levels as the total water resource approaches full development. Such conditions of full development are occurring in important areas where the costs of dealing with salinity have become a major factor in agricultural productivity and municipal-industrial treatment designs.

The salinity problem in the western U.S. is a classical case of an economic externality--the problem is created at one location and felt at another. The free market system does not include an adequate mechanism for returning the costs of salinity to the origin of the problem, and the government must ameliorate the damages through its power of regulation and its own financial resources. Provisions have been made in several legislative enactments to provide funds and guidelines to remedy individual salinity problems. However, few, if any, presently conceived salinity control programs have considered a complete array of alternatives, selected those of most cost-effectiveness, or evaluated the resulting instream impacts of the program. This report is a salinity related appendix supporting the basic planning manual entitled, "A Planning Guide for the Evaluation of

Agricultural Nonpoint Source Water Quality Controls," which is intended to provide the planning methodologies needed to develop more effective water quality strategies.

SCOPE OF REPORT

The information needed to evaluate alternative salinity control programs is generally available in a large body of technical literature. However, unless a planning group includes personnel from a number of disciplines familiar with the literature, it is extremely difficult to integrate control options into an effective and efficient framework for implementation. It is important for administrative personnel responsible for coordinating the planning exercise to be capable of judging the adequacy of the planning methodologies. To assist this individual or group, this report gives a generalized overview of important aspects of the planning problem associated with the control of salinity in irrigation return flows.

The scope of the appendix report has been restricted by three further considerations. First, the economic basis for comparing salinity control alternatives has been limited to a relatively simple minimum cost criterion. Minimum annual and annualized capital costs are accurate indicators of the relative merits of most salinity control measures and are therefore, adequate at the planning level. The other technical appendicies for this project outline the more comprehensive net benefit economic analyses that could be applied to salinity control planning. There are probably more useful towards the implementation stage when such questions as cost-sharing levels arise. In general, salinity planning must recognize the large spatial separation between source areas and impacted areas which complicate economic analyses designed for "edge of field" evaluations, particularly if the problem involves finding solutions restricted by pre-existing water quality standards.

The second limitation to the scope of this report is actually a result of the first limitation, but one with a practical basis. The array of salinity control alternatives described herein are basically structural in nature although improved management practices are implied in some cases. These are grouped into treatments of the irrigation system to improve efficiency and collecting, treating, and/or disposing of brackish irrigation return flows. Control of point sources such as saline springs, seeps, wells, etc., can be examined along with agricultural salinity control alternatives, but their control is usually straight forward.

Examining only structural alternatives is based on the fact that minimum cost criteria are usually limited to these measures. However, they also happen to be the measures most accepted, and therefore the most feasible, by land owners and irrigation districts. Land retirement, pollution taxes, subsidies and regulatory changes in irrigation practices and cropping patterns, etc., require comprehensive economic evaluation of the sort discussed in companion reports.

The third limitation is that the salinity control project is primarily concerned with the mass emission of salts. Most control measures will have only minor impacts on the concentrating effect unless irrigated acreage is reduced and phreatophyte consumption and evaporation are minimized. Thus, the primary impact of salinity control programs is generally to reduce salt pickup from water-soil weathering.

USE OF REPORT

The content and methodologies contained herein are considered by the writer to be the minimum levels of analysis that should be considered adequate in a planning document. The use of this report, therefore, should be a comparative one as well as a means to generate an assessment of the costs and associated impacts that can be expected from the implementation of selected measures. It is intended to be supplemental to the main report by addressing salinity specifically and alerting the reader to other sources of information.

The report is divided into five parts. The first given as Section 2 outlines the methodology for delineating the elements and potential solution to the irrigation-return flow salinity problem. This almost universally requires some mathematical simulation or modeling to be effective. The second part, Section 3, deals with improving irrigation conveyance efficiencies by lining to reduce seepage. This is followed by Section 4 describing methods to increase on-farm irrigation efficiency and finally by Section 5 which discusses desalting as an alternative. The report concludes with a discussion of the Grand Valley salinity control project in Colorado and demonstrates the planning methodologies described earlier.

SECTION 2

MODELING THE HYDRO-SALINITY SYSTEM

An irrigated area contributing to the salinity problems in a river or groundwater basin must be initially studied by large scale and long-term monitoring of water quality. If the problem is acute and decisions need to be made concerning the solution of the problem, the next questions are the following:

1. Which segments of the irrigation system are responsible for the salinity loadings and to what extent?

2. What would be the in-stream impacts of control measures if implemented?

The hydro-salinity system in irrigated areas is far too complex to evaluate without the assistance of computer models of these systems. The purpose of models is to systematically coordinate data input and computations which simulate the real system in order to quantify the answers to the two questions raised above. The purpose of this section is to review the modeling procedures and indicate models already available which can be utilized in the planning framework.

CONCEPTUAL HYDRO-SALINITY MODELING

Simulation of the irrigated system generally occurs at two levels. First, a mass budgeting of the local hydrology is undertaken to trace the individual impacts of various irrigation system components on the aggregate in-stream water quality. The second level is a detailed simulation of the soil and aquifer system to evaluate the chemical response of the system to changes in the various water and salt flows. Together these modeling procedures detail the causes of salinity and the effectiveness of potential solutions.

Developing Water and Salt Budgets

The process involved in formulating general water and salt budgets for an irrigated area is often referred to as hydro-salinity modeling. A schematic diagram of a general hydro-salinity model proposed by Skogerboe et al. (1979) and shown in Figure C-1, illustrates a three level subdivision of the general system used to delineate respective water and salt flows. First, as shown in Figure C-2, the irrigated system is generally a small part

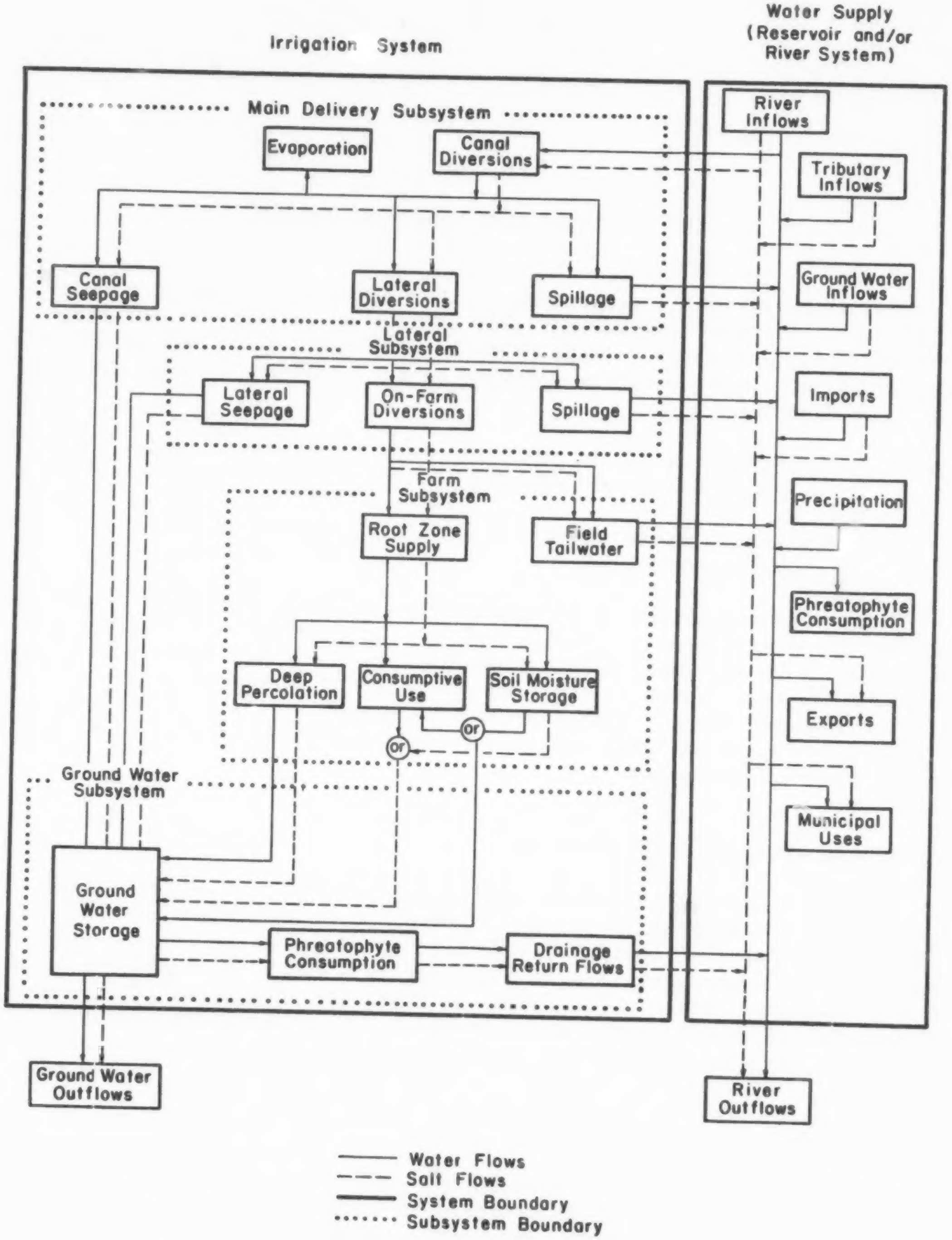


Figure C-1. Schematic of a generalized hydro-salinity model (Skogerboe, et al., 1979).

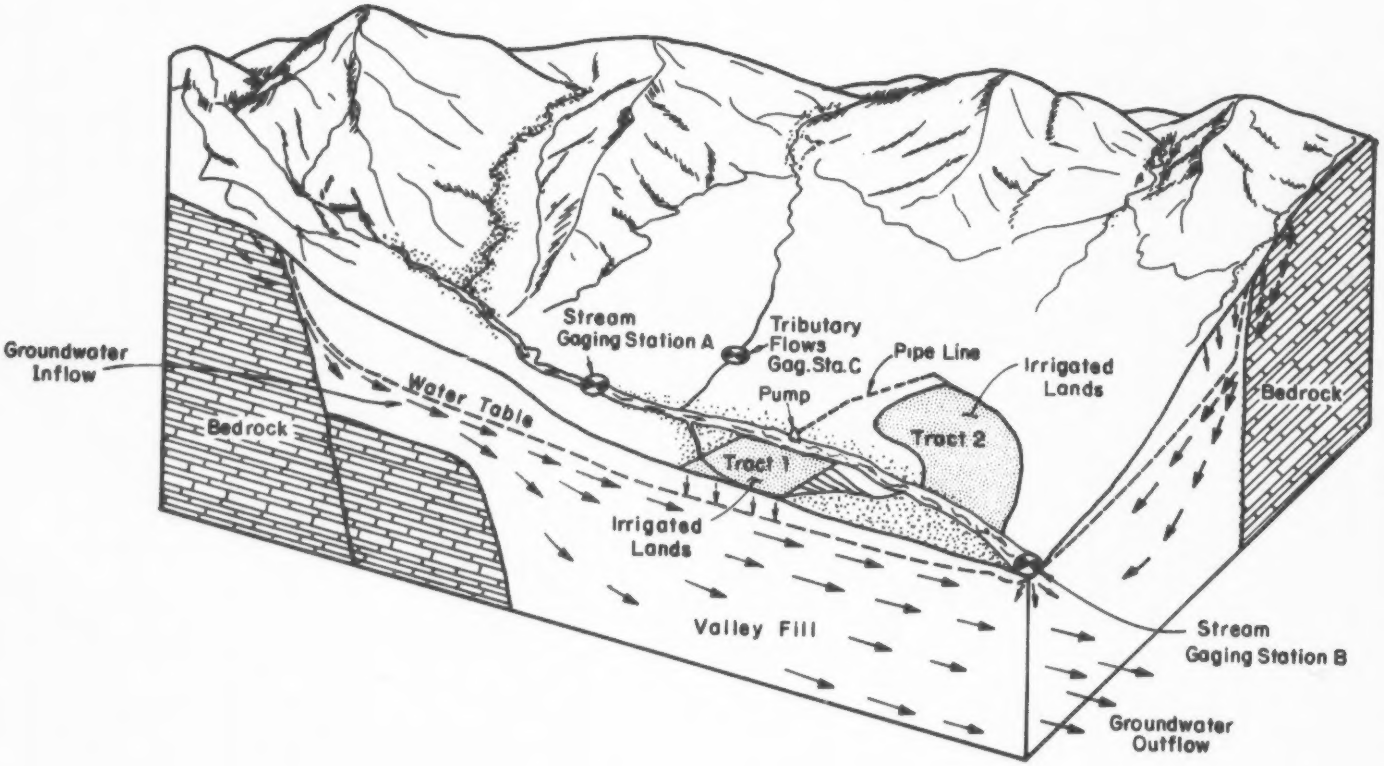


Figure C-2. The setting of an irrigated area within a typical watershed (Walker, 1978b).

of the overall hydrology in a region and must be segregated from other types of water use within the hydrologic system in which it exists. At the second level, the main conveyance, secondary or lateral conveyance, on-farm and groundwater subsystems are evaluated. And finally, within each subsystem, various hydrologic processes such as illustrated in Figure C-3, are simulated.

The most common water supply for irrigation is the surface diversion from streams, rivers and reservoirs. If the water supply to the farm is from groundwater, most if not all of the main and secondary conveyance subsystems are by-passed and the groundwater subsystem has an input loop into the on-farm subsystem. However, a discussion of the surface supply case will adequately illustrate the essential modeling functions.

Main Delivery Subsystem--

Figure 1 shows two linkages with the surface hydrology and an irrigated system. The first is the diversion of water from the water supply and the second is the return flow network comprised of surface wastes and subsurface drainage. The surface diversions, derived from data recorded by public institutions charged with administering the water supply, are divided within the main delivery subsystem into evaporative losses, seepage, diversions into the secondary conveyance network, and surface return flows (spillage). Evaporation can be estimated from climatological information whereas seepage must be based on actual measurements that will be discussed later. In some cases, diversions into the secondary conveyance networks are also based on administrative records inasmuch as this information is needed to properly allocate water among the interests of the main conveyance subsystem. Spillage is calculated by mass balance or as the difference in inflows and outflows.

Secondary Conveyance Subsystem--

The lateral subsystems convey water from the main delivery subsystem to the farms. As above, these flows may be either diminished by seepage (measurement based flow), farm deliveries (occasionally measured, generally estimated), and spillage (estimated, but often small in comparison to other flows). Evaporation is generally negligible.

Farm Subsystem--

Water and salt reaching the farm system are initially divided into field runoff (tailwater) and water entering the root zone. Tailwater is usually estimated from information describing the behavior of the irrigation method. In many cases, these flows are determined indirectly by subtracting the root zone supply from the inflows.

The important water movements within the root zone are evapotranspiration and deep percolation, with water storage changes also occurring. Separation of these flows by taking measurements on a large scale is impractical and empirical computational methods must be employed. The operation of most budgeting models assume that irrigations are applied uniformly over the cropland. Phreatophyte vegetation in the area is assumed to use water from other groundwater flows or natural precipitation which falls on the area occupied by this vegetation.

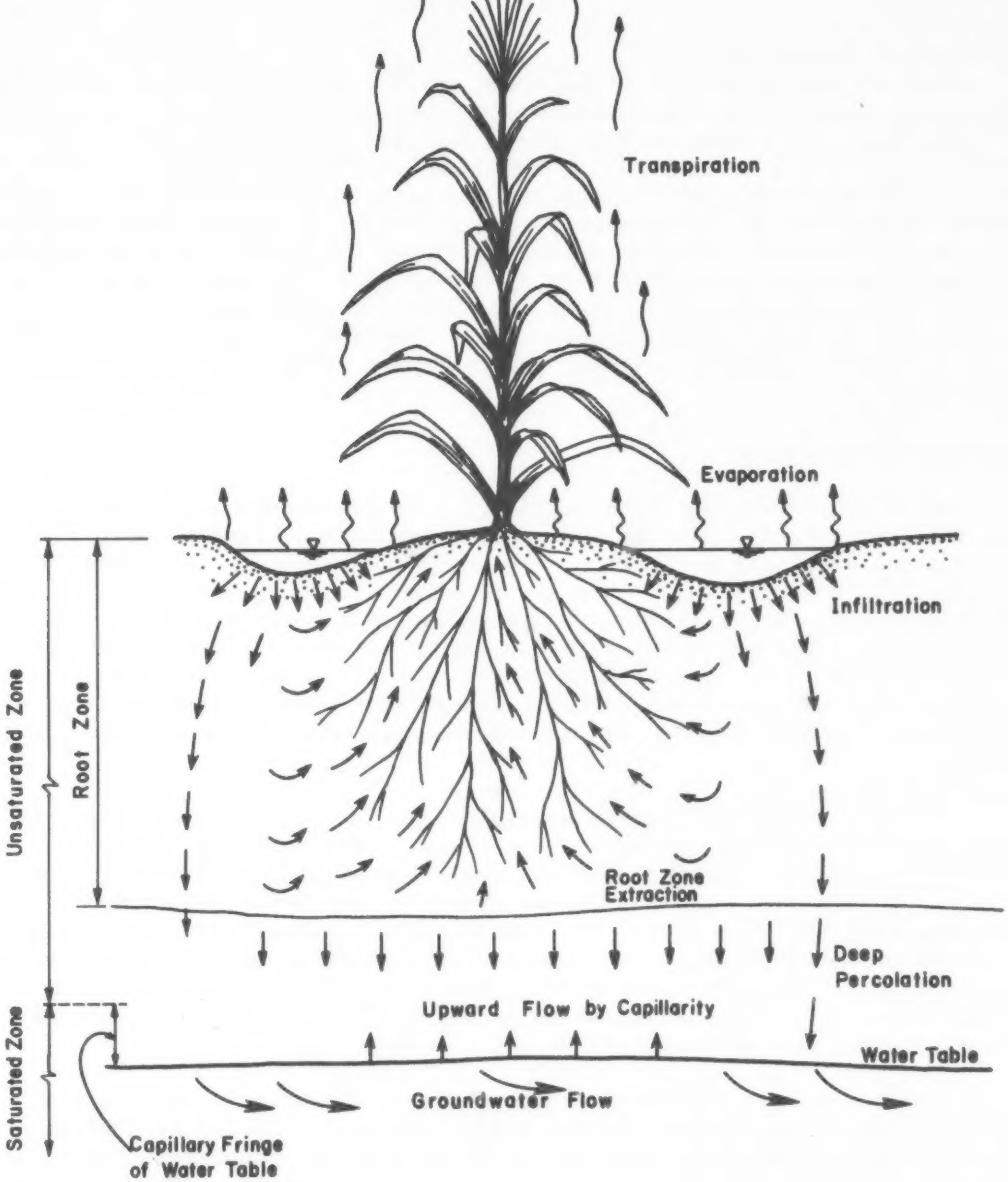


Figure C-3. An illustration of hydrologic processes comprising part of the on-farm subsystem (Walker, 1978b).

Salts in the water applied to the crops move into the root zone where they become concentrated by evapotranspiration. The behavior of specific ions is complex and not often considered at this particular level of modeling.

Groundwater Subsystem--

Most of the water in the soils and shallow groundwater aquifers originate as seepage from canals and laterals, deep percolation from the irrigation of croplands, and tributary subsurface inflows. Groundwater discharges eventually reach a local river or stream as drainage or subsurface return flows. The flows in the drainage system can be measured by installing flow measuring devices at the outflow points. Subsurface return flows are estimated from water table elevation data, the hydraulic gradients and the estimated hydraulic conductivities of the aquifer. It should be noted that in any hydro-salinity model, these estimated hydraulic conductivities contain the largest potential for error. Therefore, considerable effort must be made to properly evaluate the necessary parameters in the groundwater computations.

Detailed Simulations

Detailed simulations are used to provide refinement to the hydro-salinity models primarily in the temporal prediction of root zone and deep percolation salinities. These models can locally predict the quantity and quality of the leachate with respect to time. They can also quantify the effects of reducing irrigation return flows and the corresponding reductions in salinity. Their most valuable purpose is to establish the functions relating groundwater or deep percolation quantities and salt loading. In effect, such models are microscale hydro-salinity models that consider individual chemical reactions, the ionic constituents and the water flow system.

The hydro-salinity models generally describe the existing water and salt flow conditions in an agricultural area. Many methods for predicting the reduction in salts returning via the groundwater to the river as an outcome of salinity control measures assume a one-to-one relationship between water and salt flows. For example, when subsurface return flows are reduced by 50 percent, it is assumed that salt loading is also reduced by 50 percent. This may be a poor assumption. It is usually necessary to perform a detailed simulation to arrive at the correct relationships between the volume of return flows and the mass emission of salt.

One of the most popular detailed simulation models is the program initially developed by Dutt et al. (1972) and later updated by Shaffer et al. (1977). The model consists of three separate programs. The first program describes soil-moisture movement and distribution with time. The second program interfaces the soil-moisture movements with a chemical-biological model to reconcile differences in the soil layers used in the calculations of soil moisture and chemistry. The third program computes the chemical and biological activity occurring in the soil profile. Figure C-4 shows a block diagram of the overall model and illustrates the conceptual approach.

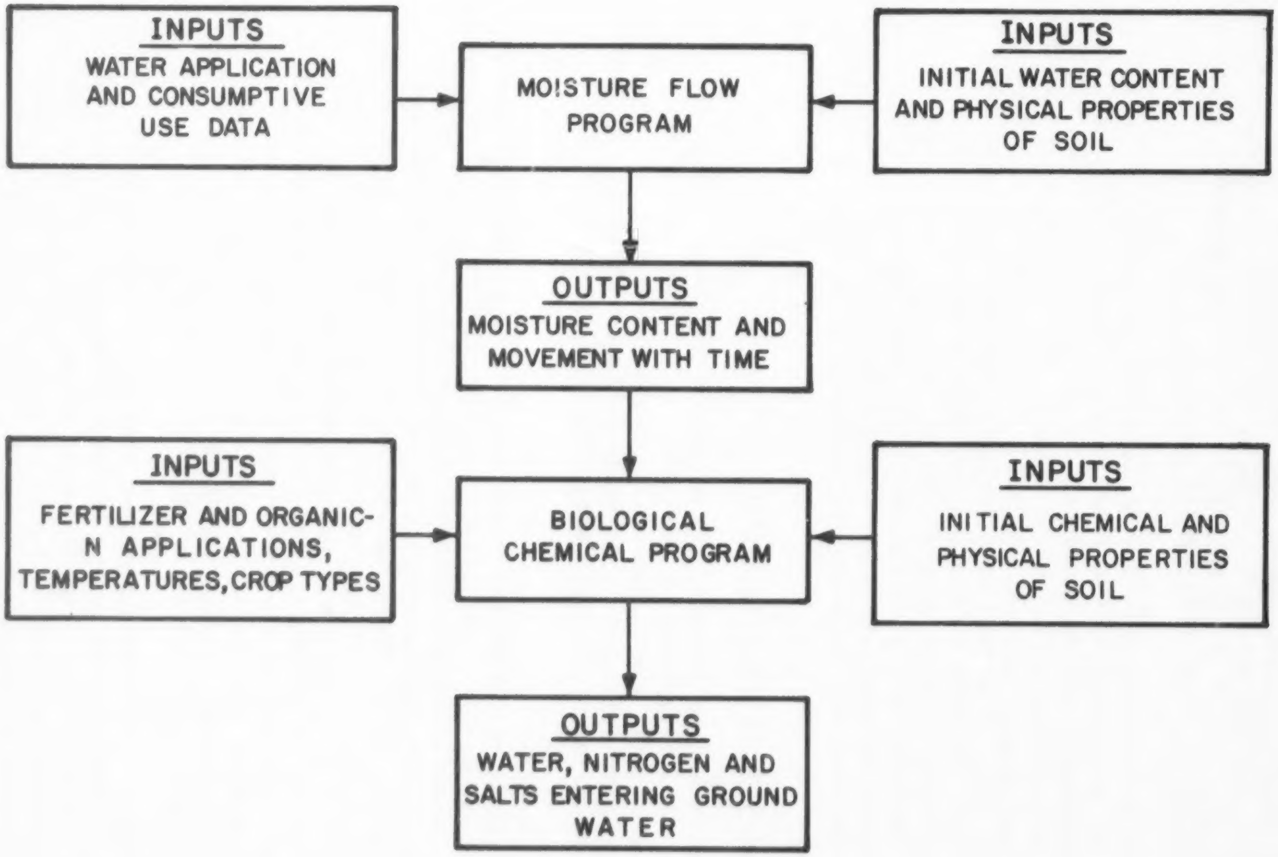

INPUTS
WATER APPLICATION AND CONSUMPTIVE USE DATA
MOISTURE FLOW PROGRAM
INPUTS
INITIAL WATER CONTENT AND PHYSICAL PROPERTIES OF SOIL
OUTPUTS
MOISTURE CONTENT AND MOVEMENT WITH TIME
INPUTS
FERTILIZER AND ORGANIC-N APPLICATIONS, TEMPERATURES, CROP TYPES
BIOLOGICAL CHEMICAL PROGRAM
INPUTS
INITIAL CHEMICAL AND PHYSICAL PROPERTIES OF SOIL
OUTPUTS
WATER, NITROGEN AND SALTS ENTERING GROUND WATER

Figure C-4. Generalized block diagram of the detailed simulation model of Dutt et al., (1972).

EVALUATION OF AVAILABLE MODELS

The use of computers in the study of the complex irrigation system processes has provided a means for their rapid and intensive evaluation. The basis for the computer codes (or models) is the expression of the real system as concise mathematical relationships with the major thrust of most models being associated with the excess water being applied to croplands. The volume of irrigation water needed to promote high crop yields is almost universally less than the volumes diverted for these purposes.

The principal interest here is the models which deal with the environmental impact of irrigation return flows (IRF). These are the models which simulate the occurrence and magnitude of the flows, their quality characteristics, and their effects on receiving waters. Recognizing that the IRF system is an aggregate of several complex hydrologic, chemical, and biological processes, this group of models also includes simulations of the basic processes. A more detailed evaluation intended to summarize modeling state-of-the-art, including a brief description of the model scope, input requirements, characteristics of the computer code, expected time and spatial resolutions, basic mathematical approach, and where possible a note concerning previous applications, calibration, or verification is given by Walker (1978b).

Scope and Resolution of Existing Models

It is convenient to classify the available IRF models into three levels of simulation: (1) simulation of the basic hydrologic, biological, and chemical processes; (2) simulation of particular subsystems of the irrigated system, and (3) simulations of large scale irrigated systems. In many cases, level 3 models consist of several integrated level 1 and 2 models.

Process Level Models--

The principal hydrologic processes in an irrigation system include transpiration, evaporation, infiltration-redistribution, and root extraction (Figure C-3). Associated with each of these processes are a number of chemical and biological transformations affecting the dissolved and adsorbed constituents in the soil. The programs classed as process level models include for the most part simulation of infiltration-redistribution, unsaturated soil solute chemistry and transport, and irrigation uniformity. Other contributions to irrigation return flows which might be categorized as process level topics, namely conveyance seepage and field tailwater, are generally not modeled independently. Root extraction, transpiration, and evaporation do not appear separately in most modeling efforts, and are therefore included in the second level of modeling.

Process level models by themselves have only marginal utility in evaluating irrigated systems unless the modeler proposes to fabricate new subsystem or system models. Two important exceptions are to be noted. First, deep percolation represents a major component of return flow. Analysis of deep percolation or leaching depends on either determining a root zone mass balance or simulating the infiltration-redistribution process. The first alternative requires more data, and is more applicable to large scale situations. Evaluating infiltration-redistribution involves shorter time intervals, less data (although more sophisticated), and yields a closer approximation to the actual event. The second exception is the analysis of the chemical-biological aspects of soils and soil solutes. Moisture flow is often better approximated by assuming steady-state conditions or that the transient nature may be represented by a series of steady-state conditions. In these cases, the quality aspects of modeling are somewhat independent of the moisture flux and can be accurately simulated by limiting the scope of the analyses. These types of models are also of benefit when computer time and core capacities are limited.

Subsystem Level Models--

The subsystem level of modeling is defined as the combination of two or more process level simulations. The main subsystem for IRF studies is the field hydrology within the irrigated system itself. In a major watershed or river basin, there are other logical subsystems describing precipitation-runoff relations, reservoir operations, instream processes like dissolved oxygen behavior, groundwater interflows, etc. Within the irrigation system itself there may be a number of similar subsystems reflecting different soils, crops, and irrigation management practices.

As with any modeling classification, subsystem models vary in the scope and dimension of their mathematics. Some models are detailed treatments of a small part of the irrigated agriculture subsystem while others are more macroscopic, large scale and time resolved treatments. The more detailed models involved basic physics and chemistry principles whereas the macroscopic approaches are generally mass continuity descriptions.

System Level Models--

As the scope and scale of IRF models increase, the variety of models also become wider. At the system level, there are two broad classes of models. The first is the models of the agricultural watershed in which one or more unsaturated zone subsystems are linked with a groundwater or drainage subsystem simulation to predict total IRF volumes and their time distributions (Figure C-5). The second set of system models are those simulating river basin or subbasin hydrology (Figure C-2). In these models, irrigated agriculture represents a small fraction of the actual land area and the emphasis is on evaluating the impact of irrigation on the system rather than quantifying its magnitude.

ASSESSMENT OF IRF MODELING CAPABILITY

If irrigation return flows are to be minimized in an area, the excess diversions and applications should approximate the water just necessary to maintain a favorable salt balance in the root zone. The capacity of conveyance and drainage systems should be reduced to the peak seven to ten day average consumptive use rates. Obviously in most situations, large capital investments for remodeling the irrigation and drainage facilities would have to be made in advance and each irrigator would require substantial retraining. It can also be argued that the agricultural scientists and

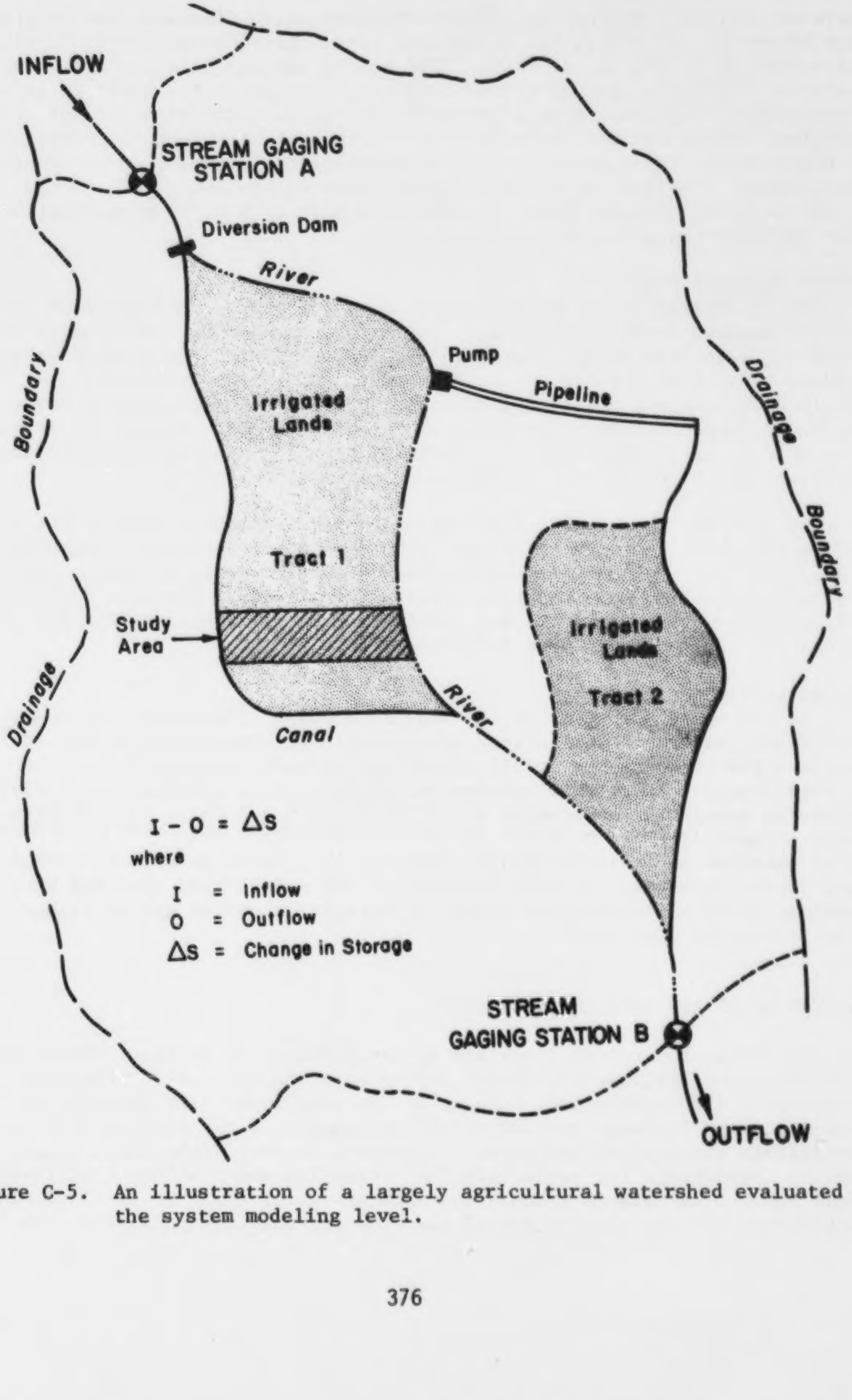


Figure C-5. An illustration of a largely agricultural watershed evaluated at the system modeling level.

engineers would need significantly better practical or "hands-on" training in order to assist the irrigator. To achieve these conditions, years of investigations must also precede the decision for implementation. The dimension of the problem needs to be defined and the effectiveness of the alternative improvements predicted. The simulation model is one of the most important tools available to planners and researchers as they seek to remedy the irrigation problem.

After evaluating these irrigated system models it becomes apparent that the existing models are almost entirely research oriented and are not easily or cheaply utilized. Planners are generally not using models to arrive at their decisions and risk the likelihood of these plans not being cost-effective. The existing models need to be thoroughly reevaluated, their parameter sensitivities quantified, and alternative simplifying assumptions assessed. A new modeling technology is needed for planning and large scale evaluations.

SECTION 3

CONVEYANCE SYSTEM SEEPAGE CONTROL

EVALUATING SEEPAGE LOSSES

There have been numerous methods developed for measuring seepage from canals and laterals involving both field and laboratory investigations. Each has its own unique characteristics that make it useful under certain conditions. The objectives of this discussion are to describe several methods that could be used as a part of salinity investigations.

The factors influencing seepage rates include: the soil characteristics of the channel bed; time of year the tests are made; length of time water has been in the channel; depth to the water table; sediment load in the water; depth of water in the channel; temperature of both the water and soil; barometric pressure; biological factors; and salts contained in both the water and soil (Robinson and Rohwer, 1959; U.S. Bureau of Reclamation, 1952 and 1963; Rohwer and Stout, 1948; Brockway and Worstell, 1968). Although the literature contains much information about the relationship between these parameters and seepage rates, the conditions found in most conveyance systems are so variable that individual field tests are generally required.

The most common methods of measuring seepage can be categorized as those that yield results indicating an average seepage from a length of channel and those in which information simply gives the permeability of a sample of the channel bed. If the latter type of measurement is employed, additional information on hydraulic gradients is necessary in order for the actual seepage to be computed. In most investigations, those methods that indicate actual seepage rates prove to be most valuable. Three of the most employed methods include the inflow-outflow method, ponding method, and seepage-meter method.

Inflow-Outflow Measurements

When the seepage rates from relatively long lengths are to be measured, the inflow-outflow method is a reliable and commonly used technique. The method consists of measuring all inflows and outflows to the canal or lateral section under investigation. By computing the net discharge loss in the channel, the actual seepage rate can be determined. Since the usual units of seepage rate are m^3/m^2/day, the conversion from the total loss in the section also requires measurements of the length and wetted perimeter (average) of the channel. The seepage rate can thus be expressed as:

$$SR = \frac{(\text{Inflow - Outflow}) \times 8.64 \times 10^4}{A} \qquad (1)$$

in which SR = seepage rate in m^3/m^2/day, 8.64×10^4 = number of seconds per day, A = average wetted area of the channel in m^2, and the difference between the inflow and outflow is expressed in m^3/sec. The canal reach must be of sufficient length so that the total seepage loss is much greater than the expected measurement error.

Although this method does give an indication of seepage rates under actual operating conditions, there are several factors that should be carefully observed or large errors will be introduced into the results. The maintenance of constant flow depths in the canal during the tests is essential to eliminate the effects of bank and channel storage changes. Also, an accounting must be made of all return flows from uplands and diversions or leaks from the canal. Occasionally, if the seepage rates are small, it may be useful to note rainfalls and evaporation, although these latter factors are generally inconsequential. Finally, flow measuring devices to be employed should be considered. In the absence of measuring structures in the system, flows generally can be measured by flumes, weirs, and current meters to accuracies of about 5 percent if operated correctly. Specialized methods such as the dye-dilution technique discussed by Liang and Richardson (1971) can be used in large channels.

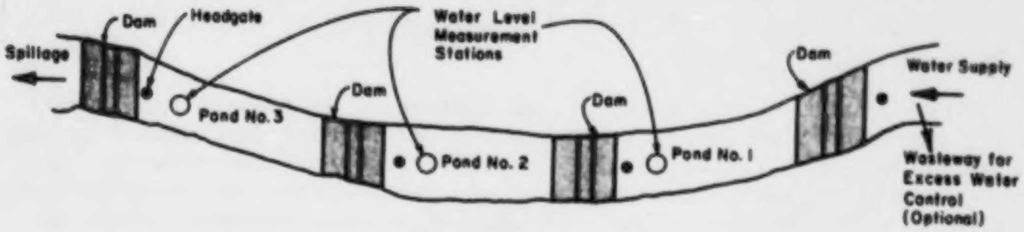
Ponding Method

Although an objection is often raised that still water may seep at a different rate than flowing water, the difference is probably small in comparison to errors associated with discharge measurement. Basically, the ponding method involves measuring the rate of fall of the water surface in the pool created in the canal section (Figure C-6). Then, by measuring length and cross-sections, it is possible to compute the seepage rate according to the following formula:

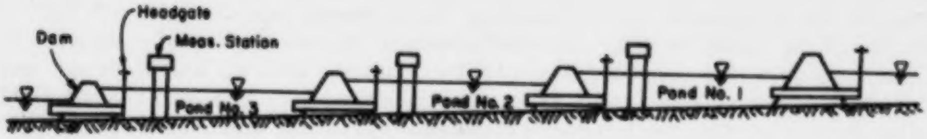
$$SR = \frac{\Delta E \times SW_a \times 24}{WP_a \times T} \qquad (2)$$

where ΔE = drop in water surface elevation in meters, SW_a = average surface width in meters, WP_a = average wetted perimeter in meters, and T = time of the run in hours.

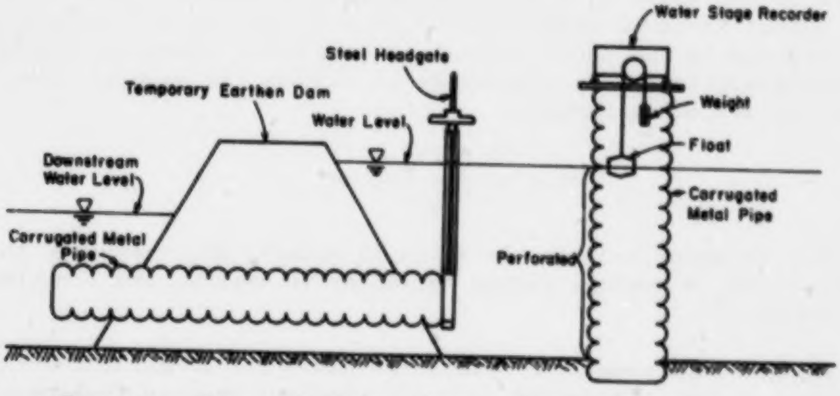
The ponding method usually provides the basis for comparison with other methods because it can be expected to yield the best results (Robinson and Rohwer, 1959; U.S. Bureau of Reclamation, 1968). It does have certain disadvantages that should be noted. Construction of the dikes is often expensive and must be completed during peiords when the canal is not in use, or during periods of interrupted canal operation. Providing water to fill the ponds may represent a significant problem. If the canal discharges are very large in relation to the seepage rates, then the ponding method is the best method by which the seepage rates can be determined. Under such conditions, errors expected in other methods, may prevent any seepage losses from being observed.


Spillage
Dam
Headgate
Water Level Measurement Stations
Pond No. 3
Dam
Pond No. 2
Dam
Pond No. 1
Dam
Water Supply
Wasteway for Excess Water Control (Optional)

Plan View



Section View
(Not to Scale)



Temporary Dam and Water Measurement Station Detail

Figure C-6. Schematic representation of the ponding test method for seepage measurement (Skogerboe et al., 1979).

Seepage Meters

Seepage meters determine seepage rates under normal operating conditions, but only for a small fraction of the total area. Nevertheless, by taking readings at several points along the canal section, a realistic average value can be determined. One type of seepage meter uses a cylindrical bell that is pressed into the channel bed. Attached to the bell via plastic hose is a plastic bag filled with water that is submerged in the channel. Water that seeps into the channel bed is replaced by water in the bag which is under the same pressure as the channel flows. Seepage from the bell is determined by weighing the plastic bag before and after the test, and the elapsed time of the test. The seepage rate then may be determined by:

$$SR = \frac{Q}{A \times T} \tag{3}$$

in which Q = the amount of water that seeped through the canal bank in m^3, A = the area of the bell in m^2, and T = elapsed time in days.

The seepage meter may be expected to work well unless the bed material is badly disturbed during meter installation. The seepage meter method is difficult to apply under conditions in which the flow depths are too great or the channel velocities are too fast. Gravel, moss, or heavily vegetated channels present difficulties in properly evaluating seepage rates.

ESTIMATING LINING COSTS

The direct contribution to local or regional salinity problems from water conveyance networks is generally the result of seepage. Seepage from canals, laterals, and ditches can be reduced or eliminated by lining with an impervious material such as concrete, plastic, or asphalt. Concrete is probably the most common lining material because of combined advantages relating to cost, ease of construction, availability, maintenance, and low permeability. For small channels, it is often advantageous to convert the conveyance to small (usually plastic) pipelines. Lining costs vary from site to site and should be estimated for each individual case.

Canal Linings

A review of concrete linings costs in the western United States by Walker (1978a) indicated a reasonably high correlation between capacity and cost. Data presented by the U.S. Bureau of Reclamation (1963, and personal communciation) and Evans et al. (1978) indicate the following general form:

$$C_c = K_1 Q^{K_2} + K_3 \tag{4}$$

in which C_c = unit lining cost, in \$/m; Q = conveyance capacity, in m^3/sec; K_1, K_2 = empirical site specific coefficients; and K_3 = fixed costs, in \$/m. The slope of the canal would affect values of K_1 and K_2 since a given discharge can be conveyed in a smaller channel if the slope is increased. Many large canals have fairly flat slopes and can be estimated with Eq. 4. If the channel slope is greater than 0.001, the coefficients should be reevaluated.

For typical July 1979 conditions, the value of K_1 was found to be 94.61, K_2 was 0.56, and K_3 ranged from \$24-\$90/m. The costs included in the first term on the right-hand side of Eq. 4 are earthwork, relocation, lining costs, service facilities, engineering and investigative and administrative expenses. Fencing, diversion, and safety structures are included in the coefficient, K_3. In an irrigation system, the discharge of the network declines along its length due to continuous withdrawal for irrigation and less acreage serviced per unit length. If it is assumed that the discharge can be linearly distributed, an expression for this distribution can be combined with Eq. 4, and then integrated over length. The resulting expression gives the total cost of lining a specific length, L (Walker et al., 1979):

$$\overline{C}_c = K_1 Q_m^{K_2} \frac{L_t}{(1 + K_2)b} \left[1 - \left(1 - \frac{bL}{L_t}\right)^{1+K_2}\right] - K_3 L \qquad (5)$$

where Q_m = inlet channel capacity, m^3/sec; L_t = total channel length, m; and b = empirical constant associated with the distribution of channel capacity.

The effect of lining a length of a particular channel on salt loadings can be based on the difference between the equilibrium salinity in return flow and the salinity in the seepage water. Walker et al. (1979) developed the following expression for estimating the impacts of channel lining:

$$S_1 = \Delta S_c N_d \Delta SR \left(\frac{Q_g - Q_p}{Q_g}\right) WP_m \times 10^{-6} L \left(1 - \frac{bL}{2L_t}\right) \qquad (6)$$

in which S_1 = annual salt loading reduction in megagrams per year (Mgm/yr) associated with lining L meters of a canal or lateral; ΔS_c = difference between the equilibrium salinity concentration in the return flows resulting from seepage and the concentration of the initial seepage flow, mg/l; N_d = number of days per year water flows in the channel, ΔSR = change in seepage rate due to the lining, m^3/m^2/day; Q_g = total volume of irrigation return flows, m^3/yr; Q_p = consumption of return flows by phreatophytes, m^3/yr; and WP_m = wetted perimeter of the canal or lateral and its inlet capacity, m.

Equations 5 and 6 indicate the cost-effectiveness of a lining program and can be combined if necessary for a single mathematical expression.

Small Ditch and Lateral Linings

Small ditches and laterals have basically the same cost-effectiveness characteristics as larger scale linings. However, three differences should be noted. First, the small capacities generally do not warrant expensive fencing, diversion, and safety structures and therefore K_3 in Equation 4 can be considered negligible. The second difference is that the operation of smaller conveyance channels is distinctly different from larger systems. Ownership is often private and sharing of flow is often rotated. Consequently, the discharge capacity generally does not diminish significantly along the channel length and Equation 5 can be simplified by letting $b = 0$.

It may be worth noting here that using the large canal values of K_1 and K_2 coefficients for small ditches may introduce significant errors. Small ditches often have larger slopes and thereby carry a given flow rate in a smaller cross-section. In addition, the construction specifications are often less stringent, thereby reducing the costs. Pipelines can be used to replace open ditches where feasible.

It is possible to provide the user of this report with some information useful in defining the coefficients in Equation 4. Typical values of slip-form concrete lining costs in the western U.S. using the sulfate resistant specifications of the U.S. Department of Agriculture, Soil Conservation Service can be approximated by

$$y = \exp - \left(\frac{y - 0.65}{9.38} \right) \qquad (7)$$

where y is the cost per square meter of lining ($\$/m^2$) and x is the perimeter of the lining in meters. Costs for ditches carrying up to 0.4 m^3/sec range from \$9/m to \$12/m.

The costs of converting a small ditch or lateral to a pipeline conveyance involves two cost estimates. The salinity or effectiveness functions are the same as given above. Irrigation pipeline materials range from plastic to concrete and metal. A typical pipeline cost using low head PVC pipe is 0.72 \$/cm of diameter/m of length and includes flow measurement, trash removal, and inlet structures.

As a general rule, slip-form concrete and low head PVC pipelines have about the same salinity control cost-effectiveness. The use of other materials in these small capacity systems represent much higher cost and are therefore not generally cost-effective in comparison.

OPTIMIZING CANAL AND LATERAL SALINITY CONTROL

Each canal or lateral network is characterized by unique values of cost coefficients, seepage rates, discharge distributions, salinity conditions, and return flow paths. As a result, there are substantial differences in the cost-effectiveness of lining various systems. Simple operation research techniques for evaluating the optimal lining program in an area have been reported by Walker et al. (1979) and Evans et al. (1981). These will not be given here, but they should be reviewed for actual planning exercises since they are simple and effective.

SECTION 4

ON-FARM CONTROL OF SEEPAGE AND DEEP PERCOLATION

EVALUATION OF IRRIGATION EFFICIENCIES

Farm investigations for nonpoint pollution control constitute the largest proportion of work involved in the evaluation of an irrigated area. Of the water applied as irrigation to croplands, some returns to the atmosphere and some returns to the groundwater and stream systems from which it was diverted. Segments of this complex system are often characterized by a chemical constituent derived from the earth materials contacted by the water.

Salinity is primarily associated with two segments of the field of hydrology: (1) on-farm conveyance seepage, and (2) deep percolation. In order to provide a direct measure of effectiveness in managing seepage and deep percolation, a modified version of application efficiency is suggested. Application efficiency, E_a, as used herein is defined as the percentage of irrigation water actually applied to the soil reservoir that is stored and then utilized from the root zone. Another on-farm return flow, field tailwater, is not included in this definition because it has a very minor effect upon salinity. Precipitation entering the soil profile should be included. Thus,

$$E_a = \frac{\Delta S_m + E_t' - P}{I} \times 100 = \frac{E_t - P}{F_d - T_w} \times 100 \qquad (8)$$

in which ΔS_m = change in soil moisture storage before and after an irrigation, cm; I = infiltrated irrigation depth, cm; P = precipitation during irrigation, cm; E_t' = evapotranspiration during irrigation, cm; E_t = evapotranspiration between irrigations, cm; F_d = field deliveries, cm; and T_w = field tailwater, cm.

The variety of structural improvements that might be effective in increasing application efficiency includes lining or piping head and tailwater ditches to eliminate seepage, conversion to alternative irrigation systems to apply water more uniformly and with better control of the application depth, and modification of existing systems such as by added flow measurement devices, land leveling, and automation.

The improvement of irrigation efficiencies through on-farm seepage control can be evaluated with the methods outlined in Section 3 except that on these small systems, the parameter, K_3, would normally be zero and

K_1 should be reduced to a value of about one-third since construction specifications are less rigid and the ditch contains fewer control structures. The use of pipe rather than concrete linings, particularly gated pipe, can also be included in this manner.

The effectiveness of amending existing systems or converting to other methods of irrigation depends on the difference in application efficiency that can be achieved. Specifically, the change in deep percolation can be written as:

$$\Delta D_p = (1 - \Delta E_a)\, D_a \qquad (9)$$

in which ΔD_p = reduced depth of deep percolation, cm; and D_a = average depth of applied water, cm.

By assuming that the soil chemical reactions can be considered in equilibrium, the prediction in salt pickup associated with a change in deep percolation is developed into the following form:

$$\Delta S_E = \Delta S_c \Delta D_p \left(\frac{Q_g - Q_p}{Q_g} \right) \times 10^{-4} \qquad (10)$$

in which ΔS_E = reduction in salt loading due to improved application efficiencies, Mgm/ha/yr.

Evaluation of the term, ΔE_a, is a difficult task. It requires that existing efficiencies be characterized and that expected efficiencies for potential improvements be predicted. Both tasks are compounded by the highly variable and diffuse nature of irrigated systems. About 70% of the irrigated lands in the United States are served by surface irrigation methods, in particular furrow, border, and basin systems.

Furrow Irrigation

Furrow irrigation is a method of water application accomplished by diverting flows into small channels which traverse the field slope. In irrigated fields, these closely spaced channels are referred to as furrows, rills, creases, or corrugations. As the irrigation water flows in the furrows, the infiltration into the bottom and sides of the furrow is redistributed in the crop root zone.

Efficient furrow irrigation requires that the inlet discharge and the duration of the irrigation be carefully coordinated with the field slope, furrow geometry, infiltration capacity of the soil, and the soil moisture holding characteristics. Crops which are subject to crown or stem injury if covered with water are often irrigated by furrows. This method is also well suited for crops which are planted and harvested in rows. The two-dimensional soil moisture movement condition is advantageous in not only minimizing the wetted surface area but also in the movement of fertilizers and pesticides toward the central root zone. The furrows are often used by irrigators in controlling the distribution of water over a field that is not uniformly graded.

The driving force for furrow irrigation is gravity, but the subsequent redistribution of soil moisture and evapotranspiration are functions of many soil-plant-atmospheric parameters. The water application itself, however, can be divided into three phases: (a) advance; (b) wetting; and (c) recession. For the normal practice of irrigating when the soil moisture reservoir has been depleted 50-75 percent, the recession phase is comparatively insignificant (Fok and Bishop, 1965). Infiltration at a specific point along the furrow begins at the moment the advancing water front reaches the point (advance phase) and continues as long as water remains in the furrow (wetting phase). When the discharge at the head of the furrow is terminated, the flow recedes down the field until reaching the end (recession phase).

The evaluation of a furrow irrigation system involves a number of alternative approaches. Detailed descriptions of the procedures are given by Criddle et al. (1956), Merriam and Keller (1978) and Walker et al. (1981). The problem is two-fold. In the initial stages of design or evaluation, the first investigative efforts are oriented toward definition of the intake relationships. Later, with a knowledge of intake characteristics, the advance and uniformities are predicted.

Field Evaluation and Infiltration--

Infiltration of water into the bottom and sides of a furrow is a two-dimensional process, the magnitude of which depends on depth of flow, furrow shape, and type of soil. Therefore, accurate information regarding infiltration characteristics may be obtained under actual flowing conditions or using a number of available on-site measurement techniques (blocked-furrow infiltrometers, inflow-outflow measurements, and cylinder infiltrometers). There are limitations associated with each procedure.

The only technique using flowing conditions for the infiltration determination is based on rate-of-advance data. This approach is based on the principle of kinematics or volume-balance and requires accurate knowledge of the water introduced at the head of the furrow (V_q) and the volume of storage in the furrow at any time (V_s).

The primary element in surface irrigation evaluations is definition of soil intake or infiltration rates. Many empirical equations have been proposed, but the most commonly employed is the relationship introduced by Kostiakov (1932):

$$i = at^b \tag{11}$$

where i = infiltration rate, cm/min; t = interval since infiltration began, min; and a,b = empirical regression coefficients. Equation 11 can be integrated over the irrigation interval to yield cumulative depth of infiltration.

Because the intake opportunity time varies in a field due to the time required for water to reach a point, the infiltrated depth over a field's length will also vary. A commonly employed function expressing the relationship between the advance rate and time is:

$$x = pt_x^r \tag{12}$$

where x = the distance along the flow path, m; t_x = time to advance x meters, min; and p,r = empirical regression coefficients. Actually, the parameter r is closely related to the infiltration exponent, b, as shown by Fok and Bishop (1965):

$$r = \exp\ (- 0.6B) \tag{13}$$

where B = b+1. Generally, r is determined by field data and then used to estimate B. Because Equation 12 is an exponential function, the slope r can be determined by knowing two points on the curve, say the time required to reach the end of the field, t_L, and the time necessary to advance one-half the field length, $t_{0.5L}$,

$$r = 0.69/\ln T \tag{14}$$

in which

$$T = t_L/t_{0.5L} \tag{15}$$

The parameter, p, however, depends on the inflow, slope, roughness, and furrow geometry. Data have been reported which tend to substantiate these conclusions, but a well verified general predictive capability for p has not been published so far as the writer now knows. Consequently, values for p must be determined for each irrigation test.

By conducting field tests to evaluate p and r in Equation 12 and then allowing B to be defined by Equation 13, only the parameter, a, remains unknown. It is however, easily defined by volume balance at the end of the advance phase. A detailed mathematical approach for this process is found in Walker et al. (1981).

The volume balance analysis has at least two important advantages for field scale evaluations. First, the approach determines an average furrow infiltration rate expression rather than the point measurements derived from other techniques. Thus, the problem of spatial variability at least along the furrow is appropriately addressed and the variability across the field can be determined by investigating a number of furrows. And secondly, the data necessary to calculate infiltration are easily determined. The investigator diverts a known and constant discharge into the furrow, notes the times until the flow has advanced one-half the field length and the field length, and measures the cross-sectional area. These data along with the field slope and length allow evaluation of the soil intake characteristics.

Predicting Application Efficiencies--

Once the infiltration coefficients have been evaluated, the application efficiency for any soil moisture deficit can be predicted. Three cases for the furrow irrigation regime may be detailed: (a) the under-irrigated case where some of the lower reaches are not completely refilled (Figure C-7a); (b) the case where the minimum irrigated area is just refilled (Figure C-7b); and (c) the general over-irrigated case (Figure C-7c).

Gerards (1978) and Walker et al. (1979) derive equations for calculating application efficiency for the three furrow irrigation regimes using three simple time ratios: (1) M = ratio of time required to infiltrated desired depth (soil moisture depletion) to total time of irrigation; (2) K = ratio of the field advance time to the time for advance flow to reach the point (X_D) where the soil moisture depletion is exactly replaced; and (3) P = ratio of field advance time to total irrigation time. Using these ratios, the application efficiency for furrow irrigations can be represented by:

$$E_a\ (UI) = \left[\frac{1}{\beta_i(P)}\ M^B K^r + \beta_i(P) - \beta_i(K) \right] \times 100 \qquad (16)$$

$$E_a(CI) = E_a(OI) = \left[\frac{1}{\beta_i(P)}\ M^B P^r \right] \times 100 \qquad (17)$$

in which UI, CI, and OI are the irrigation regimes on Figure C-7 and β_i (P)= "incomplete subsurface shape factor":

$$\beta_i(P) = n\ P^m \qquad (18)$$

$$n = 0.9598 \exp\ (-0.3383\ B) \qquad (19)$$

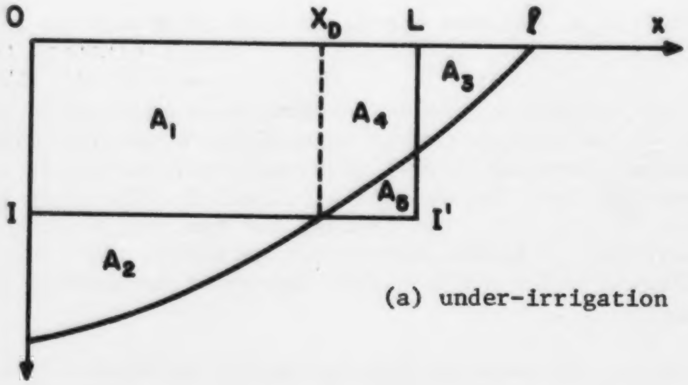
$$m = 1.0171 \exp\ (-0.9763\ B) \qquad (20)$$

Border and Basin Irrigation

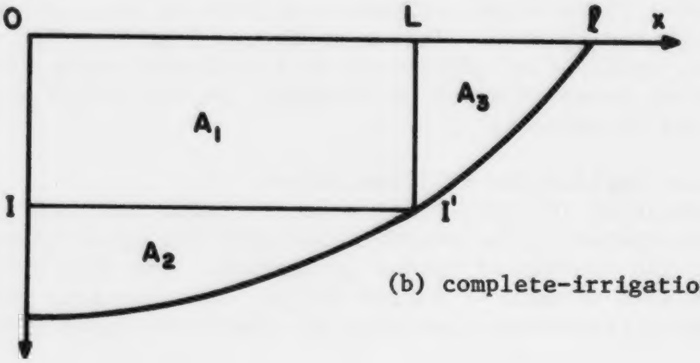
The oldest and most widely practiced methods of irrigation are border and basin irrigation. Border irrigation uses earthen dikes or "borders" to contain the water within specified boundaries. When the border has a very small slope and the end is also diked to prevent runoff, they are referred to as basins. Thus, basin irrigation and border irrigation are similar water application methods and can be considered together.

On very steep areas where land leveling costs would be prohibitive and the soils are usually not deep enough for leveling, a variation of flood irrigation using dikes is used. This method is often called guide border irrigation. Generally speaking, these "borders" are spaced fairly close together, the runs are short, and uniformities and efficiencies are low.

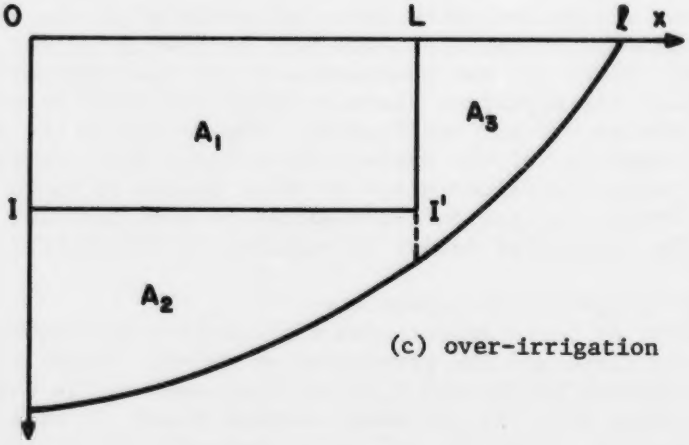
Graded border irrigation requires that the field be divided into strips varying from 10 to 20 meters or more in width and extending 100 to 800 meters in length. The slope of these "bordered strips" should not exceed



(a) under-irrigation



(b) complete-irrigation



(c) over-irrigation

Figure C-7. Definition sketch of surface irrigation application uniformity for a) the case where part of the field is underirrigated, b) the case of zero underirrigation, and c) conditions of significant overirrigation.

2 percent for row crops. Slopes can be as high as 6 percent for small grains and pastures or hay.

Irrigation efficiency of graded borders is usually about 65 percent, and the application efficiency ranges from 70 to 80 percent with proper amangement. Bos and Nugteren (1974) in a worldwide survey of irrigation efficiencies reported that the average application efficiency for graded borders was about 53 percent. The average for the United States was 57 percent. A limitation of graded border irrigation is that it generally requires considerable skill and a higher degree of management than does furrow irrigation.

The level border or basin irrigation method consists of turning relatively large streams of water into the plots surrounded by dikes or levees. This method is especially adaptable to soils with moderate to low permeability rates where other irrigation methods do not provide an adequate infiltration opportunity time. In the study cited earlier by Bos and Nugteren (1974), application efficiency on a worldwide basis for level borders and basins averaged about 58 percent. In the United States, the average value was 59 percent.

Predicting Border Application Efficiencies--

The evaluation of the infiltration coefficients for both the border and basin irrigation system can be accomplished with the water advance procedure discussed under the heading of furrow irrigation. The only analytical differences are that instead of furrow inflow, the discharge per unit width is used and the corresponding flow area is simply the depth times a unit width.

Unlike furrow irrigation where water movements after the inlet flow shut-off were neglected, these movements must be considered for the border irrigated system. There are two components of the post shut-off period. The first is called the depletion phase in which the water at the head of the border just drains off and infiltrates. The second is the recession phase where the remainder of the surface water flows from the field and infiltrates. A schematic illustration of these phases is shown in Figure C-8. The analysis of border irrigation efficiencies is more detailed than can be given here and the interested reader is referred to Strelkoff (1977).

Predicting Basin Irrigation Efficiencies--

The estimation of basin application efficiencies is somewhat simplified by the small field slope and the prevention of runoff. Water first entering the basin would advance to the end dike and then pond on the surface as illustrated in Figure C-9. As the water surface rises, it will approach a horizontal orientation. Once the inflow is shut-off, the surface profile also assures the horizontal condition. Thus, it can be seen that during the depletion and recession phases, the surface water has little or no movement, and the subsurface profile can be determined by adding the surface depths to the profile which developed during the advance phase.

The application efficiency computation for basins requires an estimate of the water depth at the head of the field (Y_o) and at the end (Y_1) as well

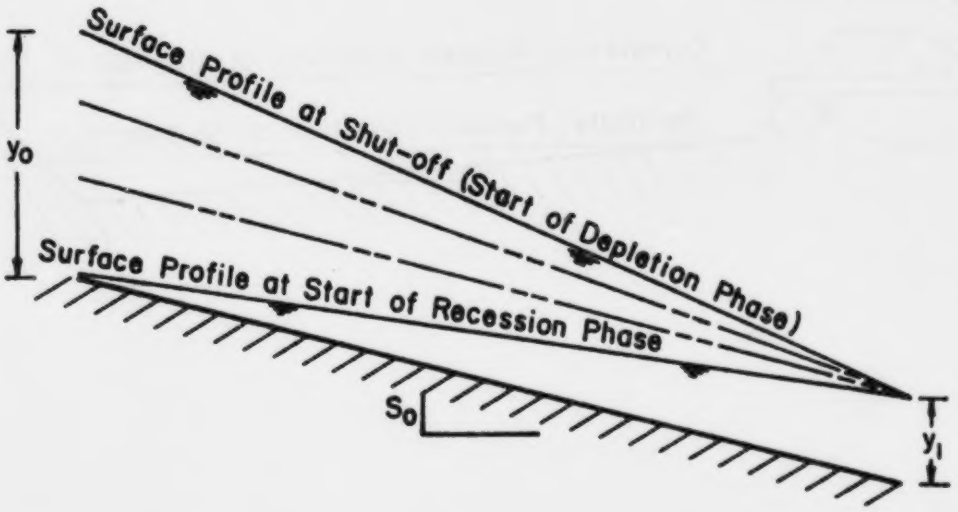

Surface Profile at Shut-off (Start of Depletion Phase)
y_o
Surface Profile at Start of Recession Phase
S_o
y_1

Figure C-8. Schematic surface profiles for border irrigation indicating the depletion and recession phases of the post shut-off period.

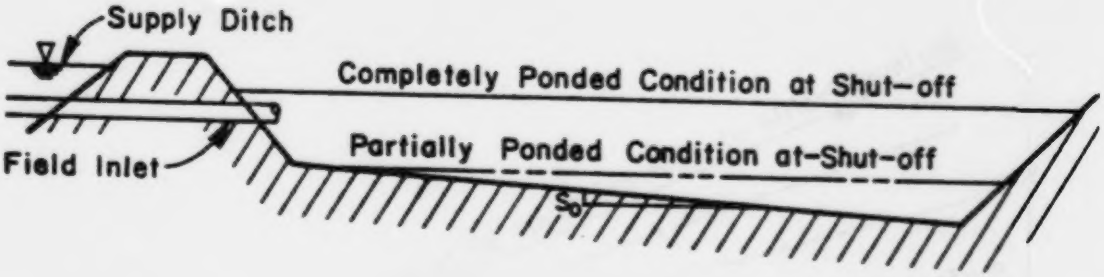

Supply Ditch
Completely Ponded Condition at Shut-off
Partially Ponded Condition at-Shut-off
Field Inlet
S_o

Figure C-9. Schematic representation of a typical basin irrigation system showing two conditions of the surface water profile following shut-off.

as the time required for the water to advance over the basin, t_L. At the cut-off time, t_{co}, the infiltrated depth at the basin inlet is $I_o = At_{co}^B$ and at the end it is $I_1 = A(t_{co} - t_L)^B$. At the end of the irrigation, these depths will be increased to:

$$I_o = At_{co}^B + Y_o \tag{21}$$

and

$$I_1 = A(t_{co} - t_L)^B + Y_1 \tag{22}$$

in which A = a/b+1 and B = b+1. Then assuming a near linear subsurface profile, the application efficiency for the basin case is:

$$E_a = \frac{2I_r}{I_o + I_1} \tag{23}$$

where I_r is the average depth of moisture required to refill the root zone reservoir.

Sprinkler Irrigation

Sprinkler irrigation systems are recommended and used on pratically all types of soils and on almost all types of crops. This type of irrigation, with its flexibility and efficient water control, has permitted a wider range of soils to be irrigated than have surface water application methods. It has thus allowed more land to be classed as irrigable. As a direct result, many thousands of hectares, which were previously considered suitable only for dryland farming or as wasteland, are being irrigated today and producing high yields. This phenomenon is particularly evident in eastern Colorado, western Nebraska, and Kansas.

Sprinklers, like most physical systems, do have disadvantages. Damage to some crops has been observed when poor quality irrigation water has been applied to the foliage by sprinklers. Also, poor quality water can leave undesirable deposits or coloring on the leaves or fruit of the crop. Sprinklers are also capable of increasing the incidence of certain crop diseases such as fire blight in pears, fungi or foliar bacteria.

Evaluating Sprinkler Irrigation Efficiency--

Because the depths of water applied over a surface irrigated by a sprinkler system are largely independent of soil properties, the efficiency analysis is based on a cumulative frequency function of the pattern uniformities. The procedure for testing sprinkler systems is outlined by the American Society of Agricultural Engineers in standard A330, and will not be repeated here. The information of interest derived from the testing is the spatial distribution of water under the wetted pattern. These data are usually collected by arranging catch-cans in a grid pattern over the area and then measuring the collected depths in each can.

The catch-can data can be used to develop a statistical measure of uniformity that can be related directly to application efficiency. Walker (1979) developed empirical equations for the relationship between the fraction of the area not receiving adequate depths, A_D, and the coefficient of variation of the pattern, v, required to refill the root zone.
The resultant expression for application efficiency, is described as follows:

$$E_a = 1 - v\,[\;3.634 - 1.123\,A_D^{0.3} + 0.003\,A_D^{1.2325}\;] \tag{24}$$

Trickle Irrigation

Trickle irrigation is a system whereby water and possibly fertilizer are applied directly to individual plants, as opposed to irrigating the entire field area as with surface or sprinkler irrigation. For orchard crops and other widely spaced crops, this is accomplished with small diameter "laterals" running along each crop row. "Emitters" attached to the lateral supply each plant with its water needs. In the case of row crops or truck crops, products are available with small diameter orifices spaced along a thin-wall hose, or porous walls through which water is allowed to escape to the soil.

With trickle irrigation, water may be provided to the crop on a low-tension, high-frequency basis, thereby creating a near optimal soil moisture environment. Because only the plants' root zone is supplied with water (Figure C-10), under proper system management little water is lost to deep percolation, consumption by nonbeneficial plants, or soil surface evaporation.

In addition to reduced water requirements and minimization of return flows, trickle irrigation has other positive advantages. These include: (a) relatively saline water may be used under proper management; (b) sloping or irregularly shaped land areas may be more easily irrigated; (c) sandy soils may be more efficiently irrigated; (d) increased production with most crops is documented; (e) irrigation labor requirements are reduced; (f) insect, weed, and disease problems are often reduced; (g) soluble fertilizers and possibly pesticides may be applied through the system; (h) harvesting and tillage operations may occur simultaneously with irrigation; (i) systems may be easily automated; and (j) the practicality of using low-yielding wells is increased. Also, there is potential for using sewage or processing effluent water as a water source.

Good system management on the part of the irrigator is very important in achieving high efficiencies with trickle irrigation systems. Some excess water is required for leaching and providing a small safety margin. Keller and Karmeli (1975) suggest $E_a = 0.90$ as a reasonable design value for most situations. Although trickle irrigation E_a values may be this high, it has proved to be somewhat less for commercially installed and operated enterprises. This is due to many factors including: (a) contractor inexperience with trickle irrigation; (b) cases where agriculturalists have underdesigned and built their own systems; and (c) irrigator inexperience with trickle system operation and maintenance.

IMPROVEMENT COSTS

A general model describing irrigation system costs for various farming conditions is not readily available. It is not a difficult task to estimate these costs if the conditions at the farm are known, but in the absence of this information, irrigation improvement costs are usually given as representative values. The objective of this section is to provide typical costs for several irrigation system improvements that are effective in reducing salinity impacts. The costs estimates will be presented in annual

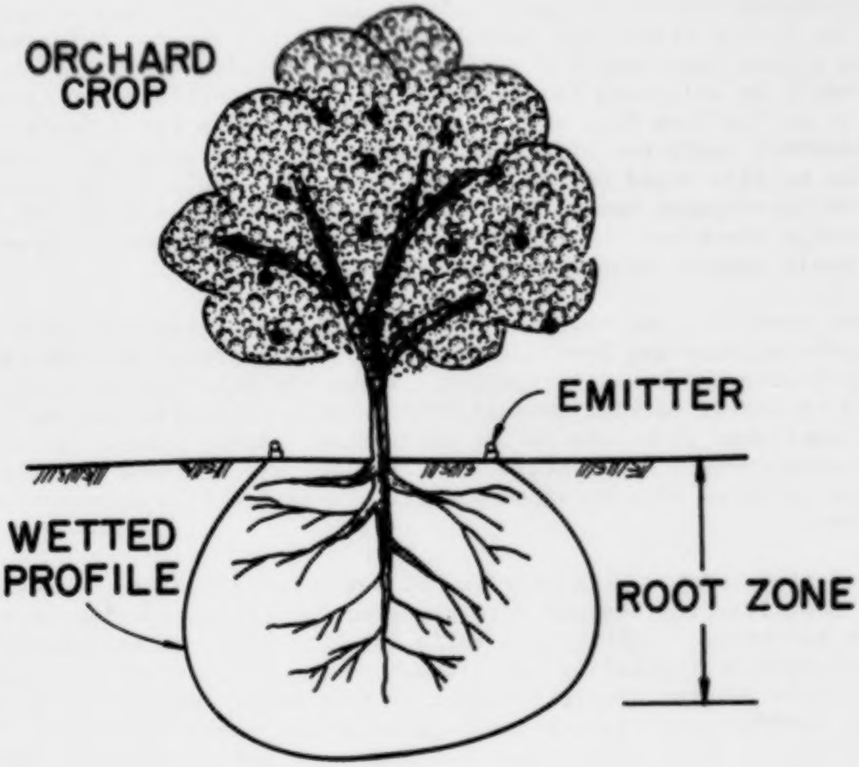


Figure C-10. Illustration of the trickle irrigation concept.

costs per hectare and will include capital and construction costs, operation and maintenance costs, and energy costs. The cost estimates are current as of February 1979.

Not all irrigating costs are included in this analysis because many are incident to the farming enterprise and do not affect the choice of system improvements for salinity control. A farmer is committed by his own choice to irrigated agriculture and is, therefore obligated in any situation to the contribution of a certain level of labor, energy, capital, and water resources. Seed, fertilizer, pesticides, taxes, and insurance are costs only minimally affected by system improvements and are not considered. Actually, many of these costs would be compensated for by higher yields and greater land value. It is obvious, then, that the costs on which a specific on-farm salinity control measure is compared with others are the differences between the total annual cost of the improved system minus the pre-implementation total annual costs and minus increases in net farm profit incurred as the result of better irrigation practices.

The pre-implementation or "base" conditions in the salinity affected regions of the United States are most likely to be the furrow irrigated field having slopes less than 1.5 percent and relatively low intake soils. The water supply is delivered to the field in unlined ditches from rivers diversions or at the farm from wells. Water supply costs are already being paid and therefore would not affect the choice of the on-farm improvement. The exception to this would be the case of the water supply being a well. If the system improvement was to be a sprinkler or trickle system, the pumping plant and energy costs must be included in the evaluation because these facilities would require substantial modification.

The base condition one might expect would also be relatively well graded, thereby eliminating leveling costs for most improved systems except for possibly border and basin irrigation. Water distribution on the farm itself would typically be with unlined ditches and application to the fields would be accomplished with cuts in the ditch bank, siphon tubes, spiles, or small check structures. New systems would replace all of these facilities except siphon tubes as well as added new structures for flow measurement and regulation.

In order to present representative estimates of irrigation system improvement costs, actual designs were prepared for fields ranging in size from 4 to 90 hectares. Quantity take-offs for materials, construction, operation-maintenance (including labor), and energy were priced and used to estimate annual costs. Typical values of crop water demands and growing seasons were used to establish system capacities and operating hours. For capital cost items, an interest rate of 7.5 percent and an expected system life of 20 years was used to annualize the cost estimates. No salvage value was given to any irrigation system component. Replacement costs for short-lived components were included in the operation and maintenance cost estimates.

All irrigation systems were analyzed under the same soil conditions (loamy soil with a moderate infiltration rate) and field slope (0.1 percent cross slope and 0.5 percent average slope in the direction of irrigation). All the systems were analyzed obtaining water from two sources: surface and groundwater supplies. A surface source is a gravity canal or a small lake or pond. No annual cost of water was assessed for surface water. Groundwater supplies were standardized as pumping electrically from 100 feet of depth, the well cased and screened with a column pipe to 150 feet. Pumps over 10 HP were all turbines. It was also assumed that one well was always capable of providing the water required. Pumps were located at the highest corner in the field, except for center pivots where the pump was located at the pivot.

The results indicate some economies of scale in the cost estimates, but given the wider variety of conditions actually existing in the field, it is probably only justified to give average figures. Consequently, the costs for the various field sizes were averaged. The results, presented in Table 1, includes capital, O & M, and energy costs for several of the most common irrigation system improvements.

TABLE C-1. TOTAL ANNUAL COSTS OF SELECTED IRRIGATION SYSTEMS AND IMPROVEMENTS FOR SELECTED ALTERNATIVES

Description of System or Improvement	Annual Costs, $/ha
Concrete Ditch Linings	40
Gated-pipe Replacement of Head Ditches and Pipes Connecting Systems	35
Automated Cutback System	100
Gated-pipe Tailwater Recovery and Reuse System	147
Big Gun Traveler Sprinkler System	480 to 644[1]
Solid-set Sprinkler System with Above Ground Aluminum Piping	667 to 800[1]
Solid-set Sprinkler System with Below Ground PVC Piping	947 to 1065[1]
Hand Move Sprinkler System with Aluminum Piping	327 to 453[1]
Sideroll Sprinkler System	218 to 295[1]
Center Pivot Sprinkler System	146 to 199[1] [2]
Trickle Irrigation Systems for Orchards and Widely Spaced Row Crops	458

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[1] Range of costs for surface water supplies (small values) and groundwater supplies (large values)

[2] For center pivot systems covering more than 32 ha.

One can see that annual costs cover a wide range in the irrigation industry. Simple head ditch linings are more than an order of magnitude, cheaper than most of the pressurized conversions. However, the improvement in application efficiency is also a factor in the cost-effectiveness of the measure as a salinity control alternative. Head ditch linings would improve the irrigation efficiency by the amount of seepage prevented whereas the remaining improvements also create increases due to better water control and uniformity.

DEVELOPING ON-FARM COST-EFFECTIVENESS FUNCTIONS

The development of cost-effectiveness functions for the on-farm segment of a salinity control program follows the same two step procedure outlined earlier for the canal lining alternatives. A detailed procedure is given by Walker et al. (1979). The application efficiency of the existing system and that expected from the improvement are determined from the evaluation of the irrigated system using previously described methodologies. The net increase in application efficiency is utilized along with the average annual depth of applied water to determine the changes in deep percolation. This value is then used to define the annual salt reduction achieved by the increased application efficiency. Thus, the elements of the cost-effectiveness function are defined:

$$\overline{C}_f = (C_f/\Delta S_E)\ S_f \qquad (25)$$

where $\overline{C}_f$ = annual cost of reducing salinity by S_f, Mgm/yr; C_f = annual per hectare cost of the irrigation system improvement; and ΔS_E = reduction in salt loading due to improved application efficiencies, Mgm/ha/yr.

SECTION 5

DESALINATION

INTRODUCTION

The traditional scope of saline water conversion programs has been to reclaim otherwise unsuitable waters for specific needs. However, this scope has dealt almost exclusively with utilization of product water directly rather than returning it to receiving waters to improve water quality. With mounting concerns for managing salinity on a regional or basin-wide scale, the potential for applying desalination within the framework of an overall salinity control strategy might be feasible. For instance, the use of desalting systems to resolve critical salinity problems is planned as part of the Colorado River International Salinity Control Project agreement between the United States and the Republic of Mexico (U.S. Department of the Interior, 1973).

For regional salinity control evaluations, desalting costs are expressed in dollars per unit volume of salt extracted in the brine discharge rather than the conventional index of costs per unit volume of reclaimed product water. In this manner the respective feasibility of desalination and other alternatives for salinity management can be systematically compared during the processes of developing strategies for actual implementation of salinity controls. A desalting system as used herein consists of facilities for supplying raw water (water to be desalted) to the plant, the desalting plant itself, and facilities to convey and dispose of the brine (Figure C-11). Transportation of product water beyond the confines of this system is not considered.

The cost simulations described in this section are based on two major references. Prehn et al. (1970) summarized a desalting cost calculation procedure for several desalting methods and related facilities. This work was subsequently improved and expanded by the Bureau of Reclamation (U.S. Department of the Interior, 1972). These costing procedures were mathematically simulated and then programmed for a digital computer by Walker (1978a).

For most agriculturally oriented uses of desalination, electro-dialysis and reverse osmosis are likely to be the major processes. Since reverse osmosis (RO) can treat a wider range of brackish waters, it is used in this report (Figure C-12).

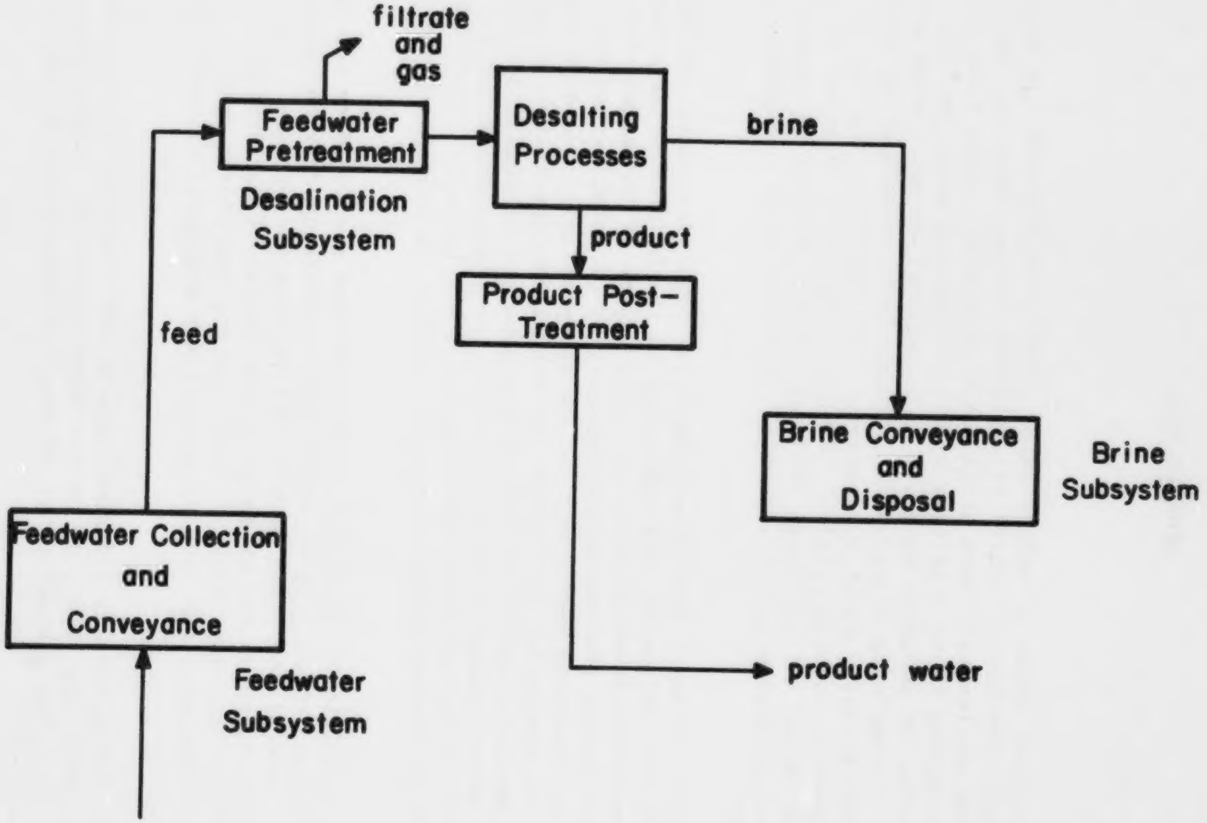

Figure C-11. Schematic diagram of a typical desalination system.

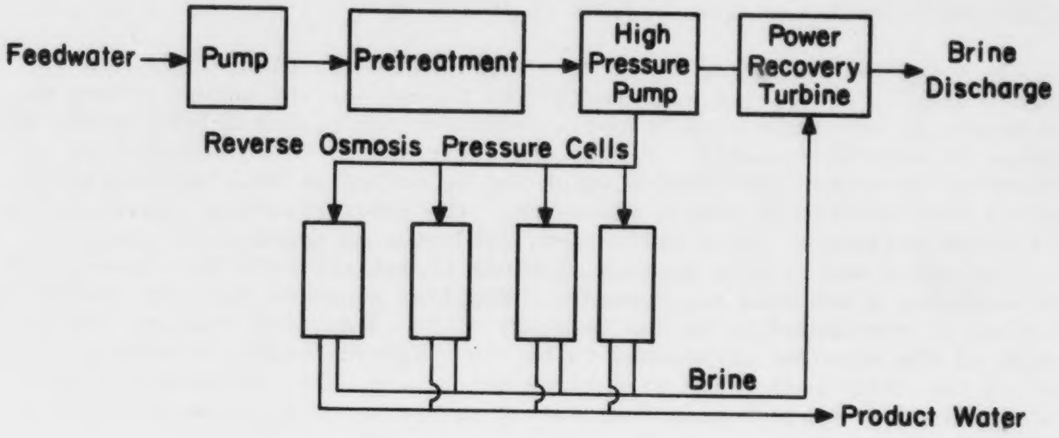

Figure C-12. Flow diagram of typical RO desalting system.

The reverse osmosis process uses hydraulic pressure to separate water and salts via a semi-permeable membrane. Energy consumption is proportional to the quantity of salts to be removed. Consequently, the most economic application of RO plants should be to soft, warm feedwaters having 1000 to 10,000 mg/ℓ TDS and producing water of 100-500 mg/ℓ.

Two vessels of water having different salt concentrations and separated by a semi-permeable membrane (permeable to water but exclusive of salts) will produce a flow of relatively pure water from the dilute solution to the more concentrated until either they are both the same concentration or a buildup of pressure in the latter stops the process. This phenomenon is called osmosis. It should also be noted that the more substantial the initial concentration differential, the greater the pressure (osmotic pressure) necessary to stop the flow. If a pressure greater than the osmotic pressure is applied to the solution of higher salinity, the flow of water can be reversed.

The variety of waters that might be desalted by any system includes sea water, brackish and saline groundwater, and brackish surface waters including irrigation return flows. Many of these waters contain substances deleterious to desalting plant operation. Dissolved gases and organic materials are usually controlled by deaeration and ultrafiltration. However, one of the principle problems in desalination systems is the potential for scaling due to high concentrations of calcium. As a general rule, waters having calcium concentrations above 600 mg/ℓ should be pretreated (such as the injection of a polyphosphate). In this study, it is assumed that sodium hexametaphosphate is utilized in all cases and that by so doing, the allowable calcium concentration in the feedwater is 900 mg/ℓ. The total dissolved solids concentration is also limited to 10,000 mg/ℓ.

In a typical desalting complex, a significant fraction of the annual expenditures is associated with facilities to collect and convey feedwater, and to convey and dispose of brines. Feedwater facilities in this study are limited in several respects. First, the water supply to be desalted is assumed to be either groundwater which can be collected with well fields or surface flow capable of simple diversion. (No costs have been attributed to surface diversions.) After collection, feedwater is conveyed by concrete pipeline which may require pumping stations to satisfy both the transmission and desalting plant head requirements. Pipeline capacity for cost estimating purposes is considered to be the capacity of the desalting complex. The length of the pipeline is assumed to be the weighted average connector serving the individual wells or surface diversions. The relatively high cost incurred by these assumptions should insure a conservative estimate of desalting costs.

DESALTING COST-EFFECTIVENESS

While recognizing the site-specific nature of desalting technology as applied to regional water quality management, some generalization of the cost-effectiveness relationships can be made. A detailed evaluation of input parameters to a desalting cost analysis was presented by Walker (1978a). All systems are most sensitive to the capacity of the desalting plant. When the costs are expressed in terms of salt removal, the unit costs stabilize to nearly constant values when the capacities are greater than about 10,000 to 15,000 m^3/day. Since desalting would be most competitive with the salinity control alternatives when the unit costs are minimal, only systems with capacities greater than 15,000 m^3/day can be considered. The result of this consideration is that the desalting cost-effectiveness functions become linear.

For the purpose of formulating a desalting cost-effectiveness function which can be evaluated along with other salinity control measures, the model by Walker (1978a) was updated to April 1979 conditions. Then the model was used to generate cost-effectiveness curves for feedwater salinities ranging from 1,000 to 11,000 mg/ℓ. These functions shown in Figure C-13 were then condensed into the following mathematical form:

$$\overline{C}_d = 0.5 + M'S_1 \qquad (26)$$

in which $\overline{C}_d$ = annual cost in \$/million of removing S_1, Mgm/yr x 10^3; and

$$M' = 1404\ TDS_1^{-1.18} \qquad (27)$$

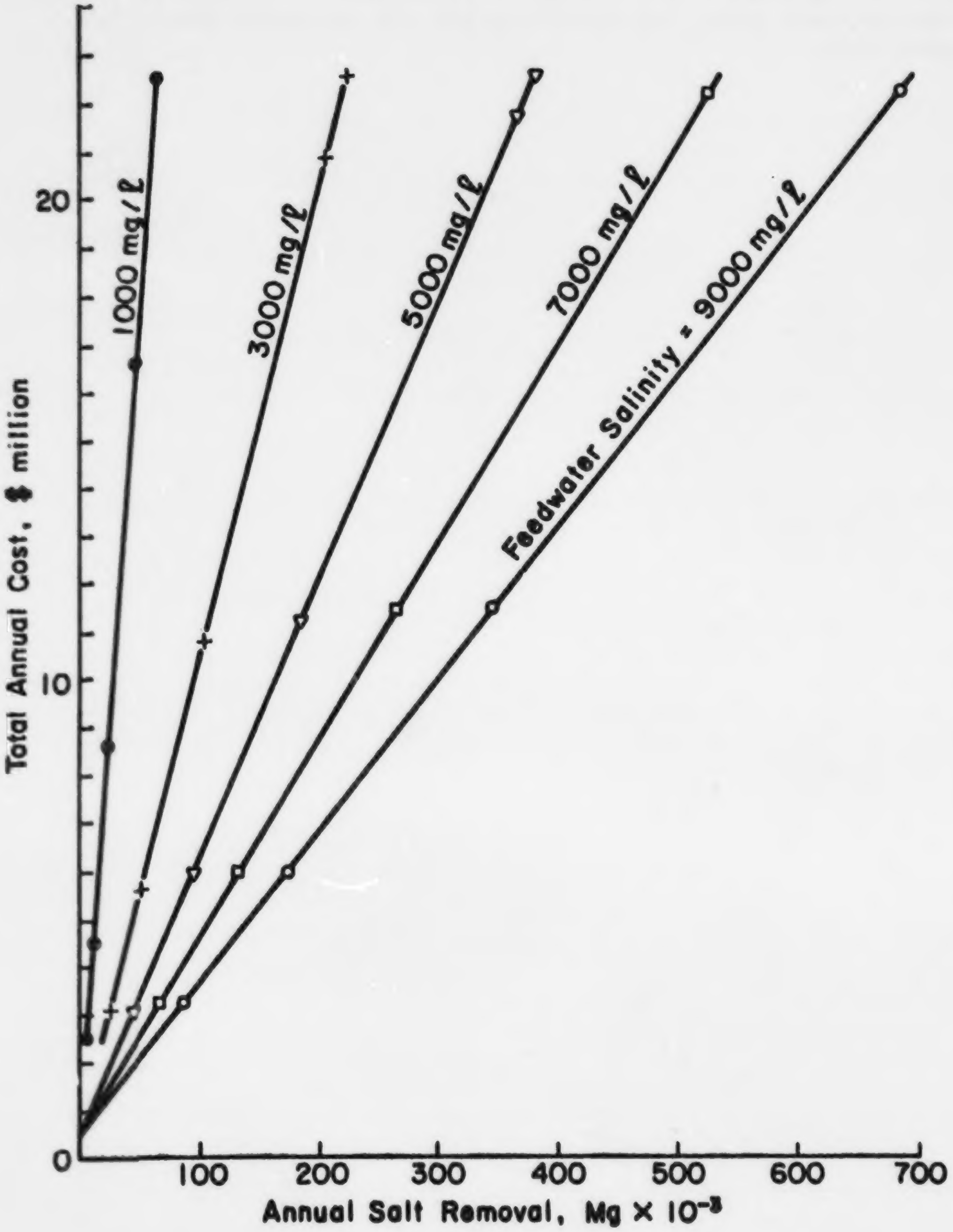

Figure C-13. Annual costs of salt removed by reverse osmosis desalination process at various feedwater concentrations.

Where TDS_i = feedwater salinity, mg/ℓ. The input data used to generate Equation 26 should be fairly typical of those generally encountered in or near agricultural areas, and therefore, the cost estimates should be representative.

SECTION 6

CASE STUDY: GRAND VALLEY SALINITY CONTROL

INTRODUCTION

Several irrigated areas in the Western U.S. would qualify as salinity control case studies, but only the Grand Valley in western Colorado has experiences the broad spectrum NPS planning procedure. A large body of technical literature has been generated by local research and demonstration studies. The purpose of reiterating some of it here is purely to illustrate the NPS procedures.

This manual is premised somewhat on the assumption that the primary pollution problem in most areas would be identified before the NPS planning techniques would be instituted. Consequently, this case study will begin by giving a brief summary of the problem identification phase of the Grand Valley study. References will be presented for the reader interested in more detail concerning the studies conducted to delineate the basic elements of the hydro-salinity system. After describing the physical system, the case study will concentrate on evaluation of alternative BMP's and the optimization of the candidate measures to arrive at the best set of salinity control practices for the Grand Valley.

IDENTIFICATION OF SALINITY PROBLEM

Colorado River Salinity Problem

Salinity is the most serious water quality problem in the Colorado River Basin (Figure C-14). The impact, felt largely in the Lower Basin, is acute because the Basin is approaching conditions of full development. Increasing salinity concentrations are threatening the utility of water resources in the downstream areas of Arizona, California, and the Republic of Mexico. Detriments to agricultural water users are primarily being encountered in Imperial and Mexicali Valleys, while the primary urban detriments are occurring in Los Angeles and San Diego. The U.S. Environmental Protection Agency (1971) reported that existing damages to Lower Basin users would increase from $16 million annually in 1970 to $51 million annually by the turn of the century if planned developments do not include appropriate salinity control measures. More recent estimates by the U.S. Bureau of Reclamation show present damages at $53 million annually, with projections to $124 million annually by the year 2000 (Bessler and Maletic, 1975). Annual costs of salinity increases have been estimated to be from $10 to

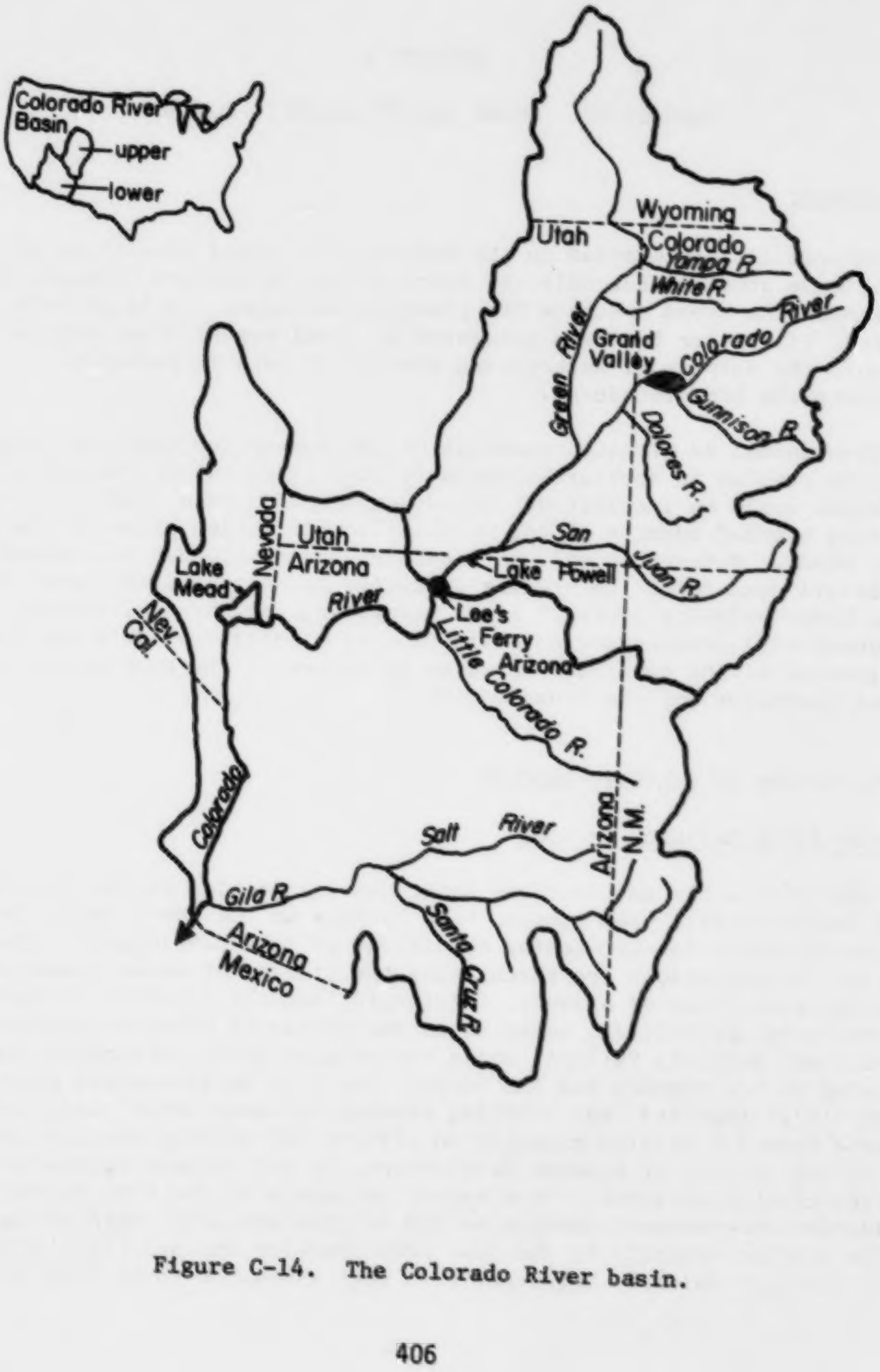

Figure C-14. The Colorado River basin.

$18 per megagram (Mgm) increase per year (Bressler and Maletic, 1975; Valentine, 1974; Walker et al., 1978).

Approximately 9.7 million Mgm of salts are delivered each year in the water supply serving the Lower Colorado River Basin. These salts reach Hoover Dam in about 1.59 x 10^{10} cubic meters of water. Studies have indicated that roughly 37 percent of this salt load is contributed by irrigated agriculture in the Upper Colorado River Basin.

As the result of the mounting problem, a concerted effort to identify the sources of salinity in the Colorado River Basin indicated that the Grand Valley in western Colorado (Figure C-15) was one of the largest per hectare agricultural sources of salinity (about 18 percent of the total Upper Basins' agriculturally related contribution) (U.S. Environmental Protection Agency, 1971). This area subsequently became the site for the first studies to evaluate field-scale salinity control measures.

General Description of the Grand Valley

Location and Setting--

The Grand Valley is located in west central Colorado near the western edge of Mesa County. Grand Junction, the largest city in Colorado west of the Continental Divide, is the population center of the valley. The valley is a crescent shaped area which encompasses about 49,800 hectares of which about 25,000 hectares are irrigated. Urban and industrial expansion, service roads and farmsteads, idle and abandoned lands account for most of the land not farmed. The valley was carved in the Mancos Shale formation (a high salt bearing marine shale) by the Colorado River and its tributaries. The Colorado River enters the valley from the east, is joined by the Gunnison River at Grand Junction and then exits to the west.

An economic survey by Leathers (1975), along with the land use inventory by Walker and Skogerboe (1971), indicates that local farming is primarily a small unit operation. The population engaged in agricultural activities is widely dispersed throughout the valley with most living on their property. Leathers (1975) determined from sampling about 100 random selections that most farm units were less than 40 hectares in size. Of the total 7,870 fields in the valley, 50 percent are less than 2 hectares in size [United States Department of Agriculture--Soil Conservation Service (USDA-SCS), 1976].

The Grand Valley recieves an average annual precipitation of only 211 mm and practically all irrigation and potable water supplies come from the nearby high mountain snowpacks. The climate is marked by a wide seasonal range, but sudden or severe weather changes are infrequent due to the high mountains surrounding the valley. The usual occurrence of precipitation in the winter is snow and during the growing season is in the form of light showers from thunderstorms. Severe cloudbursts occur infrequently during the late summer months and hail storms are rare. Although temperatures have ranged to as high as 40.6 °C, the usual summer temperatures range to the middle and low 30's in the daytime and around 15°C at night. Relative

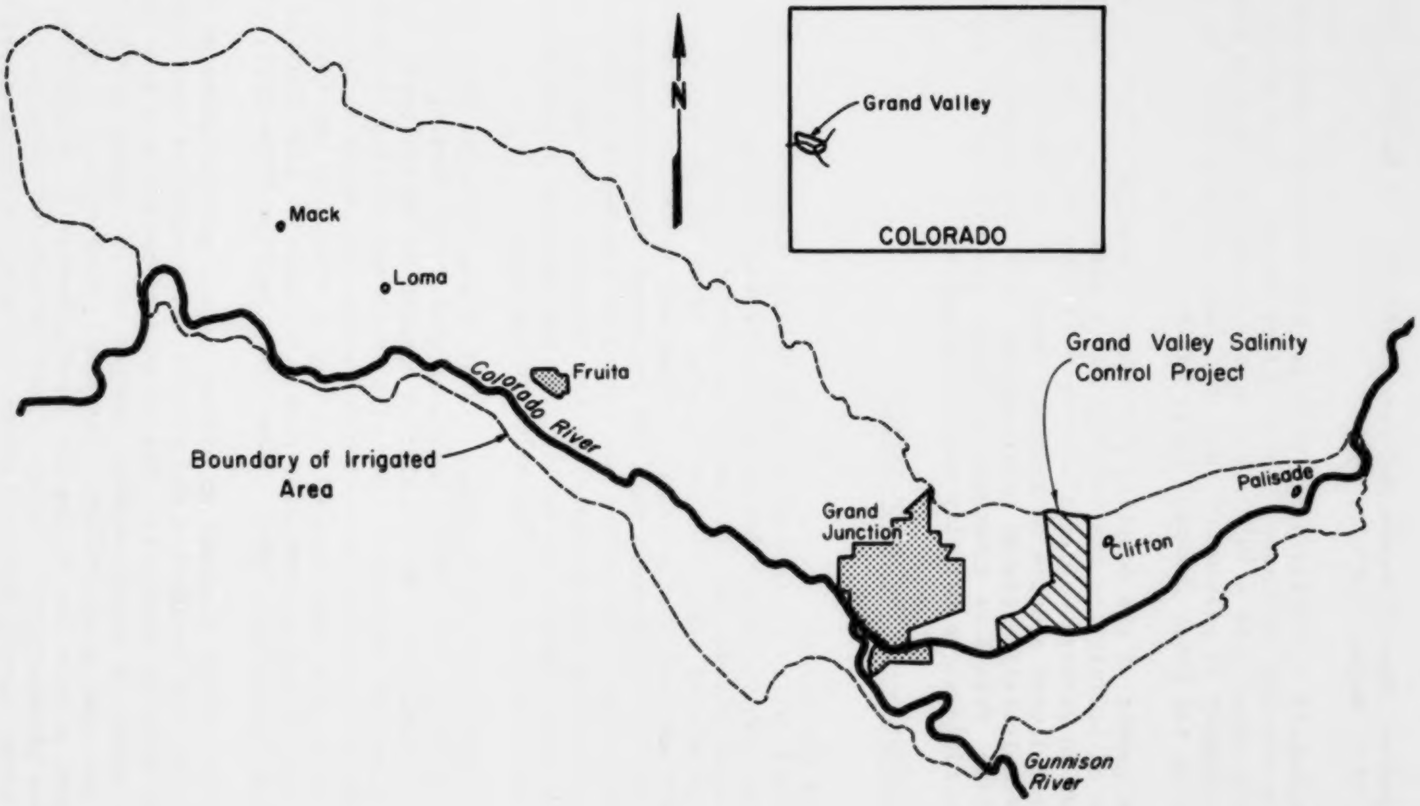

Figure C-15. The Grand Valley, Colorado.

humidity is usually low during the growing season, which is common in all of the semi-arid Colorado River Basin. The average annual relative humidity is 58.8 percent. The prevailing wind direction is east-southeast with an average velocity of about 13.4 kilometers per hour.

Irrigation--

Two main irrigation entities divert water from the Colorado River. These are the Grand Valley Water Users Association and the Grand Valley Irrigation Company. A third irrigation company, the Redlands Power and Water Company, diverts water from the Gunnison River. A number of smaller companies have carriage agreements with the two major canals for delivery of Colorado River water. The irrigation system of the valley currently consists of about 287 kilometers of canals and ditches.

Discharge capacities at the head of the irrigation canals range from 20 cm^3/sec in the Government Highline Canal to 0.8 m^3/sec in the Stub Ditch and diminish along the length of each canal or ditch. The lengths of the respective canal systems are approximately 74 kilometers for the Government Highline Canal, 35 kilometers for the Price, Stub, and Redlands Ditches, 125 kilometers for the Grand Valley system, and 53 kilometers for the Orchard Mesa Canals.

Laterals are small conveyance channels which deliver water from the company canals to the farmer's fields. These small channels usually carry flows less than 0.14 m^3/sec and range in size up to 1.2 or 1.5 meters of wetted perimeter. There are about 600 kilometers of laterals in the Grand Valley as determined by the U.S. Bureau of Reclamation (USBR) (1976). Not counting the Redlands area of the valley, there are 1,553 laterals in the valley (USBR, 1976).

Single users served by an individual turnout are not uncommon, but most laterals serve several irrigators who decide among themselves how the lateral will be operated. Most of the multiple-user laterals, which may serve as many as 100 users, run continuously throughout the irrigation season with the unused water being diverted into the drainage channels. USBR (1976) figures show that the average irrigated acreage served by a lateral is between 10 and 15 hectares. The prevalent method of applying water to croplands in the valley is furrow irrigation.

Geology--

The geologic formations throughout the Colorado River Basin were laid by an inland sea. After the retreat of the sea, the land masses were uplifted and subsequent erosion has created the mountains and plateaus as they are today. The upper formations are sandstones and marine shales which are underlain by the marine Mancos Shale and the Mesa Verde formations Mancos Shale is a very thick formation that lies between the underlying Dakota sandstones and the overlying Mesa Verde formations. The thickness of the Mancos Shale usually varies from between 900 to 1,500 meters. Due to its great thickness and its ability to be easily eroded, this shale forms most of the large valleys of western Colorado and eastern Utah.

The Grand Valley was created by erosion cutting through the upper formations creating the valley in the Mancos Shale. The shale contains lenses of salt which are easily dissolved as water moves over the shale beds. Water moving over and through the shale originates from overirrigation and leakage from the canals and laterals. Since the overlying soil is derived from the shale, it is also high in salts and contributes significantly to the salinity of return flows.

Defining the Hydro-Salinity Systems

The Impact of Irrigation on Salt Loading--

The Grand Valley was identified as an important agricultural source of salinity in the Colorado River Basin through a water and salt mass balance. Iorns et al. (1965) evaluated stream gaging records for the 1914 to 1957 period, concluding that the net salt loading (salt pickup) from irrigation ranged from about 450,000 to 800,000 Mgm annually. Similar analyses by Hyatt et al. (1970), Skogerboe and Walker (1972), and the U.S. Geological Survey (1976) substantiated this range of salt loadings. Most studies indicate an average, long-term salt pickup rate of between 600,000 to 700,000 Mgm/year. This mass of salts is added primarily by irrigation return flows, thereby necessitating a delineation of the components and practices.

The irrigation return flow system in the valley may be divided according to whether or not the return flows are surface or subsurface flows. Surface flows occur as either field tailwater or canal, ditch, and lateral spillage. Subsurface flows include canal and ditch seepage, lateral seepage, and deep percolation from on-farm applications (deep percolation in this sense to include head ditch and tailwater ditch seepage).

Canal and ditch seepage--Since the early 1950's, five major seepage investigations of the major canals and ditches have been conducted (Skogerboe and Walker, 1972, and Duke et al., 1976). Although seepage rates have been noted over a wide range, a representative rate is 0.061 m^3/m^2/day. In the Grand Valley, the total canal seepage is estimated to be approximately 3,700 ha-m per year.

Lateral seepage--Tests reported by Skogerboe and Walker (1972) and Duke et al. (1976) indicate seepage losses from the small ditches comprising the lateral systems probably average about 8 to 9 ha-m/km/year. Thus, for the 600 km of small laterals, the total seepage losses are approximately 15,300 ha-m annually. Combined lateral and canal seepage is, therefore, approximately 9,000 ha-m annually.

On-farm deep percolation--Numerous studies in recent years have attempted to quantify deep percolation from on-farm water use. Skogerboe et al. (1974a, 1974b) estimated these losses (including head ditch and tailwater ditch seepage) to be about 0.30 ha-m/ha. Duke et al. (1976) estimated these losses, independent of on-farm ditch seepage, to be 0.15 ha-m/ha. Kruse (1977) presents information showing on-farm ditch seepage to be 0.12 ha-m/ha. Combining the figures given by Duke et al. (1976) with

Kruse (1977) gives a total on-farm subsurface loss of 0.27 ha-m/ha. Total on-farm seepage and deep percolation losses are therefore, about 7,500 ha-m per year.

Canal spillage and field tailwater--The operational wastes and field tailwater are difficult to define because, first, they do not generally create problems associated with salinity degradation, and second, data regarding these flows are sparse. Skogerboe et al. (1974a) listed field tailwater as 43 percent of field applications, whereas Duke et al. (1976) reported estimates of field tailwater and canal spillage or administrative wastes which were 18 percent and 35 percent, respectively. Estimates of spillage and tailwater by the Bureau of Reclamation were slightly smaller than the first estimate. Using the 43 percent figure for field tailwater and the 18 percent figure for canal spillage yields about 37,000 ha-m per year for field tailwater and spillage.

Aggregating the data presented previously with inflow-outflow records in the vicinity of Grand Valley gives a clear picture of how the irrigation system relates to the overall hydrology (Figure C-16). The flow diagram is particularly helpful in visualizing the relative magnitude of the irrigation return flows from the agricultural area in comparison with the flow in the Colorado River. A more detailed summary of an annual Grand Valley water and salt flow is given in Table C-2.

Adding up the individual contributions to the groundwater and dividing the figure into the mass of salts contributed annually to the river gives an estimated salt loading ratio of 3.82 by 10^{-3} Mgm/m^3. This figure assumes an annual salt contribution, from the agricultural portion of the watershed, of 630,000 Mgm/year. Thus, the contributions from canal seepage, lateral seepage, and on-farm deep percolation are respectively, 140,000 Mgm/yr., 205,000 Mgm/yr., and 285,000 Mgm/yr.

DEVELOPMENT OF BMP'S

The first steps in the salinity control planning framework after the problem identification phase are to delineate the array of alternatives for controlling salinity. Those that appear acceptable can then be evaluated and demonstrated under field conditions to identify the practicable solutions. These field data describing not only the effectiveness of the solution but their associated costs as well are then combined in an optimizational context to determine BMP's.

Identifying Potential and Appropriate Solutions

The description of the hydro-salinity system in the valley pointed out the likelihood of the salinity system being in a saturated condition. As a result, any salinity control alternative that would diminish the flow of subsurface return flows would be effective. In fact, the relationship between groundwater control and salinity control is approximately linear. Therefore, the potential solutions that might be applied would include most if not all of the measures described earlier. In many other areas, the

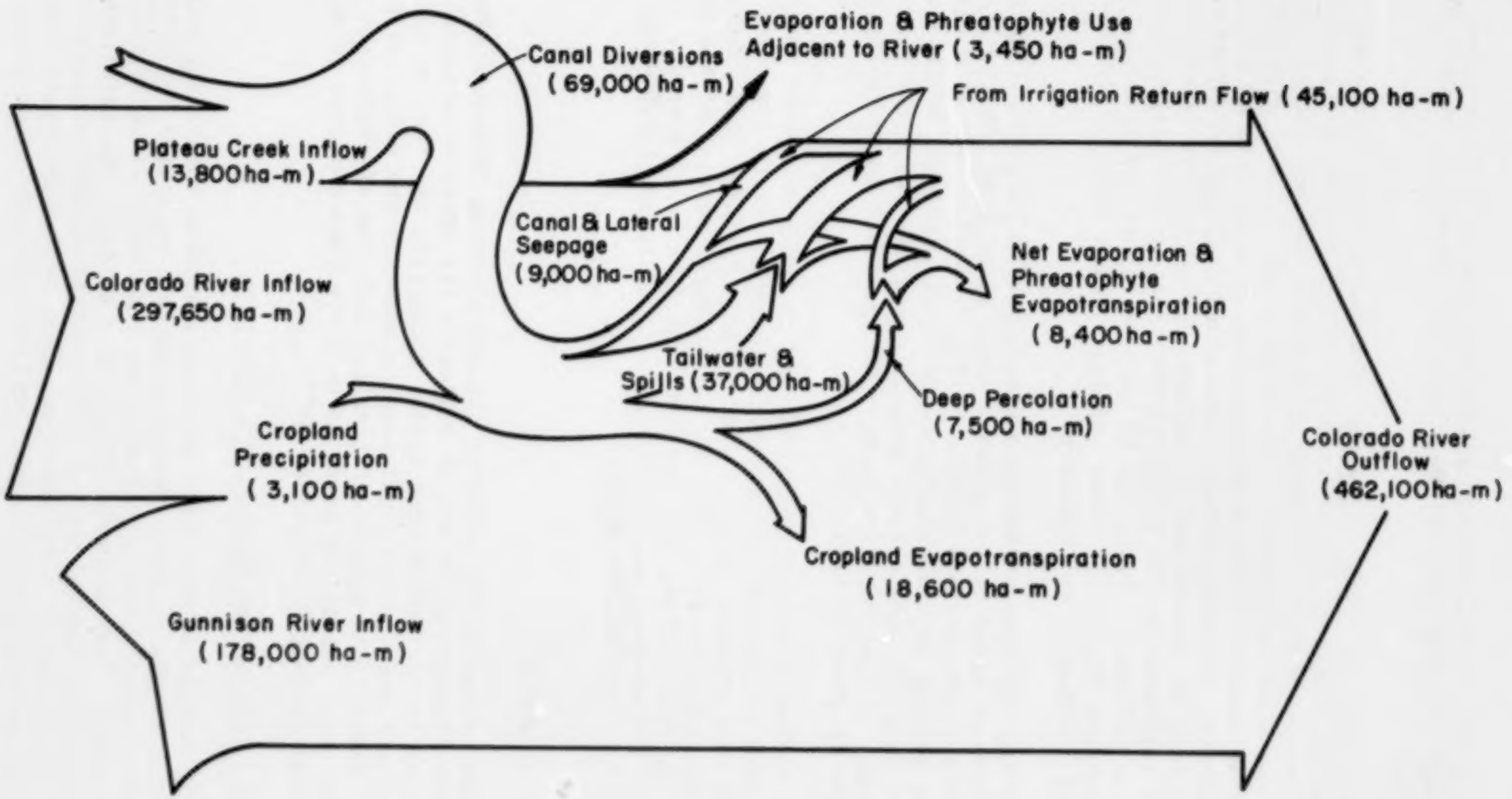

Figure C-16. Mean annual flow diagram of the Grand Valley hydrology.

TABLE C-3. MEAN ANNUAL GRAND VALLEY WATER AND SALT BUDGETS (WATER UNITS IN HECTARE-METERS, SALT UNITS IN Mgm).

	Water	Salt
River Inflows		
Plateau Creek	13,800	62,600
Colorado River near Cameo	297,650	1,352,600
Gunnison River near Grand Junction	178,000	1,371,700
	489,450	2,786,900
Evaporation and Phreatophyte Use (net)	3,450	--
Canal Diversions		
Lateral Diversions	52,900	301,100
Seepage	3,700	21,100
Operational Wastes	12,400	70,600
	69,000	392,800
Lateral Diversions		
Seepage	5,300	30,200
Field Tailwater	24,600	140,000
Cropland Consumptive Use	18,600	
Cropland Precipitation	-3,100	
Deep Percolation	7,500	130,900
	52,900	301,100
Irrigation Return Flows (Subsurface)[a]		
Canal Seepage	3,700	163,200
Lateral Seepage	5,300	232,200
Deep Percolation	7,500	416,800
Phreatophyte Withdrawals (net)	-8,100	
	8,100	812,200
Irrigation Return Flows (surface)		
Operational Wastes	12,400	70,600
Field Tailwater	24,600	140,000
	37,000	210,600
River Outflows		
Colorado River at Colorado-Utah State Line	462,100	3,445,900[b]

[a] This segment of the budget includes all salt pickup and mass balance for salts will not be achieved.

[b] Includes 30,000 Mgm of naturally contributed salts.

Note: 1 ha-m = 8.108 acre-ft; 1 megagram = 1.102 English short tons.

list would not be so extensive. For instance, in areas where individual irrigators pump groundwater, the measures which impact conveyance systems could be omitted directly.

If the problem associated with this case study demands remedy in the near future, then many of the potential solutions of an institutional nature are not appropriate because their implementation is currently restricted by the existing legal system. For example, influent standards, water markets, taxation, etc., require basic changes in both the administrative framework now in place as well as laws governing water resource use. A salinity control planner would likewise need to evaluate each of the other alternatives and develop a list of appropriate solutions. For the purpose of this case study it will be assumed that the list of appropriate solutions includes only the following technological measures: the conveyance system can be lined or piped, the irrigation system improved or modified, and the brackish return flows collected and desalted. It should be noted in passing to the next step in the procedure, that the process of selecting appropriate solutions from the array of potential solutions, has essentially arrived at this simplifying assumption. As a general rule, salinity control programs will nearly always emphasize the "structural" components among the available options.

Field Demonstration and Evaluation

As a means of developing basic information concerning the multitude of salinity control alternatives, the Grand Valley Salinity Control Demonstration Project was set up in 1968. The demonstration project area. shown in Figure C-15, was located a few miles east of Grand Junction and comprised about 1,300 irrigated hectares. The area was initially selected because it was representative of the Grand Valley and had five canals traversing the area, thereby allowing greater participation by the irrigation companies in the valley. The demonstration and evaluation was divided into three phases all of which involved detailed hydro-salinity investigation to define the effectiveness and costs of the salinity control practices. Details of the studies are reported by Skogerboe and Walker (1972), Skogerboe et al. (1974a, 1974b) and Evans et al. (1978).

The first phase of the demonstration project was an evaluation of canal and lateral linings as salinity control measures. More than 12 kilometers of canals and seven kilometers laterals were lined with slipform concrete and gunite. Seepage measurements before and after the linings along with a detailed hydro-salinity budgeting effort indicated that salt loading had been reduced by approximately 4,300 Mgm/yr. The total cost was $420,000. It became apparent during this first phase that the conveyance system was not the major salinity contribution in the valley. As a result, a second phase was launched to investigate the benefits of irrigation scheduling and drainage.

The evaluation of irrigation scheduling, indicated that irrigation scheduling would have a small effect on improving on-farm water management because the existing irrigation systems did not allow irrigators to evaluate how much water they were applying. The scheduling could be expected, however, to be more effective if farmer confidence could be gained and certain structural improvements such as flow measurement devices were made. The evaluation of drainage centered on the feasibility of field drainage as a salinity control alternative. Waters percolating below the crop root zone can be intercepted by the field drainage system before the salts in the lower subsoils and aquifers can be dissolved. One field drainage system was built as part of this project and was successful in intercepting the flow as intended. It was found, however, that the cost per Mgm of control was approximately two orders of magnitude greater than any of the other alternatives.

The canal lining, irrigation scheduling, and drainage studies were evaluated individually. In order to extend these research results to the formulation of comprehensive plans for salinity control on a valley-wide scale, it was necessary to evaluate the interrelationships which existed among these and other alternatives. To do this, a two part effort was initiated in 1973, as the third phase of the project. The first part involved a highly refined research investigation into the physical and chemical processes of salt pickup from local soils. The second part was a large demonstration of the combined effects of several irrigation improvements.

The results of the first part have been published (Skogerboe et al., 1979) and are only of interest here because they show the salt pickup rates per unit of groundwater flow.

The primary objective of the second part of this phase of the demonstration project was to show the advantages of implementing a "package" of technological improvements within the lateral subsystems in reducing the salt load entering the Colorado River. As defined by this project, the lateral subsystem began at the canal turnout and included all of the water conveyance channels below the turnout and the farmlands served by the lateral subsystem. Although major emphasis was upon on-farm improvements, considerable improvements in the water delivery conveyances and some improvements in lowering high water tables (drainage) were also required. This phase of the project utilized each of the salinity control measures previously evaluated with the additional use of various irrigation methods.

In order to facilitate the continued participation by the irrigation interests in the Grand Valley, the laterals were selected to cover as many canals as possible. The final selection had two laterals under the Highline Canal, one under the Price Ditch, three under the Grand Valley Canal, and three under the Mesa County Ditch. The laterals were selected to capitalize on previous work regarding canal and lateral lining, irrigation scheduling, and drainage studies.

The experimental design for the preevaluation was primarily aimed at providing specific information for the 330.7 hectares undergoing treatment. The field data collection program allowed the design of irrigation and drainage facilities and provided sufficient data to allow predictions of salinity benefits which resulted from each specific salinity control measure. Although the postevaluation included the monitoring of water and salts entering and leaving the demonstration area, the primary emphasis was the on-site evaluation of each specific salinity control measure.

The types of planned treatments included sprinkler irrigation, drip irrigation, concrete lateral linings, concrete head ditches, gated pipe, automated cut-back furrow irrigation, land shaping and clearing, flow measurement, tailwater removal systems, buried PVC plastic irrigation pipelines, agricultural field drainage, irrigation scheduling, and various improved water management practices for each subsystem. In some cases, only increased labor spent on irrigation, in conjunction with one other type of treatment, was incorporated into the experimental design.

The total improvements completed in the project area since 1969 as part of the demonstration of salinity control include: 12.2 km of large canal linings, 16,432 meters of perforated field drainage tile, construction of a wide variety of on-farm improvements, and an irrigation scheduling program. The costs of the various improvements totaled almost $750,000. The total combined improvements remove almost 12,300 Mgm of salt per year. The resulting "average" cost-effectiveness is $5.98 per Mgm assuming 7.5% interest rate and a 20 year facility life. The resulting benefit-cost ratio based on downstream damages of $14.71 per Mgm/yr was 2.50 to 1.

Optimizing BMP's

Optimization procedures can be used to determine the best overall selection of projects based on some criterion such as minimum cost. For the purpose of this case study, four groupings of salinity control alternatives will be considered: (1) canal and ditch lining; (2) lateral linings; (3) on-farm improvements; and (4) desalination of return flows. The first and third groupings will involve the use of optimization to identify the best project selections.

Canal and Ditch Lining--

The Grand Valley irrigation system involves fourteen canals and ditches ranging in size and operating characteristics. The first step in the optimization of a canal lining strategy is to formulate the cost-effectiveness function for each canal or ditch system. Utilizing the equations outlined by Walker et al. (1979) the costs of lining various fractions of each canal were determined. These data and the resulting salinity reductions were fit with the simple cost-effectiveness fraction:

$$\bar{C}_c = \frac{S_1}{AS_1 + B} \qquad (28)$$

in which $\bar{C}_c$ is the cost in dollars of lining sufficient meters of a particular canal to achieve a salinity reduction of S_1, Mgm/yr. The coefficients A and B, are regression constants, a summary of which for each of the fourteen canals is given by Evans et al. (1981).

The next step was to determine the optimal canal lining strategy given the alternatives represented by the fourteen canal system cost-effectiveness functions. The results of the optimization process are shown in Figure C-17. These data can also be fitted with a function like Eq. 28 to yield a second level or general canal lining cost-effectiveness function as indicated in the figure.

In order to illustrate the use of Figure C-17, consider the consequences of a decision made as the result of subsequent or higher level optimization to reduce seepage related salinity in the Grand Valley by 50%. Figure C-17 indicates that the total controllable salinity achieved by linings is approximately 110,000 Mg/yr. Fifty percent of this salt reduction is therefore 55,000 Mg/yr and from Figure C-17 can be achieved at a minimum cost of $26 million or about $2.5 million annually.

Lateral Linings--

The Grand Valley lateral system generally runs in the north-south direction. The average land slope in this direction is a little more than 1% which is sufficient gradient to handle most flows in the smaller sizes of slip-form concrete ditch or pipelines with diameters from 30 to 38 mm. Thus, it can be expected that lateral lining cost-effectiveness is essentially a linear function and basically the same for each lateral subsystem. Utilizing an average discharge of 0.1 m^3/sec, the per meter lateral lining cost was found to be $26. Thus, the total cost of lining the 600,000 meters of lateral would be about $15.6 million.

The salinity contribution from lateral seepage was discussed previously as 205,000 Mgm/yr. If the lateral linings can be assumed to be effective for 20 years and the project interest rate is 7.5%, then the cost-effectiveness of lateral linings on an annual cost basis is $7.46/Mgm.

On-Farm Improvements--

The various on-farm salinity control measures which are adaptable to the Grand Valley can be grouped into three general classes:

(1) Lining farm ditches to prevent seepage;

(2) Improve water application uniformity and efficiency by modifying existing systems or converting to more effective irrigation methods; and

(3) Irrigation scheduling and irrigator training.

The existing application efficiencies in the Grand Valley can be evaluated from Table C-2. Walker et al. (1979) shows that 52,900 ha-m of water are delivered annually to the head of the lateral system, of which, 47,600 ha-m are diverted at the farm turnout. The average application efficiency as defined earlier was about 67%. As noted previously, this part of the agricultural system contributes an estimated 285,000 Mg of salt per year to the Colorado River. The cost-effectiveness of various measures to reduce this salt loading and their optimal integration is discussed below.

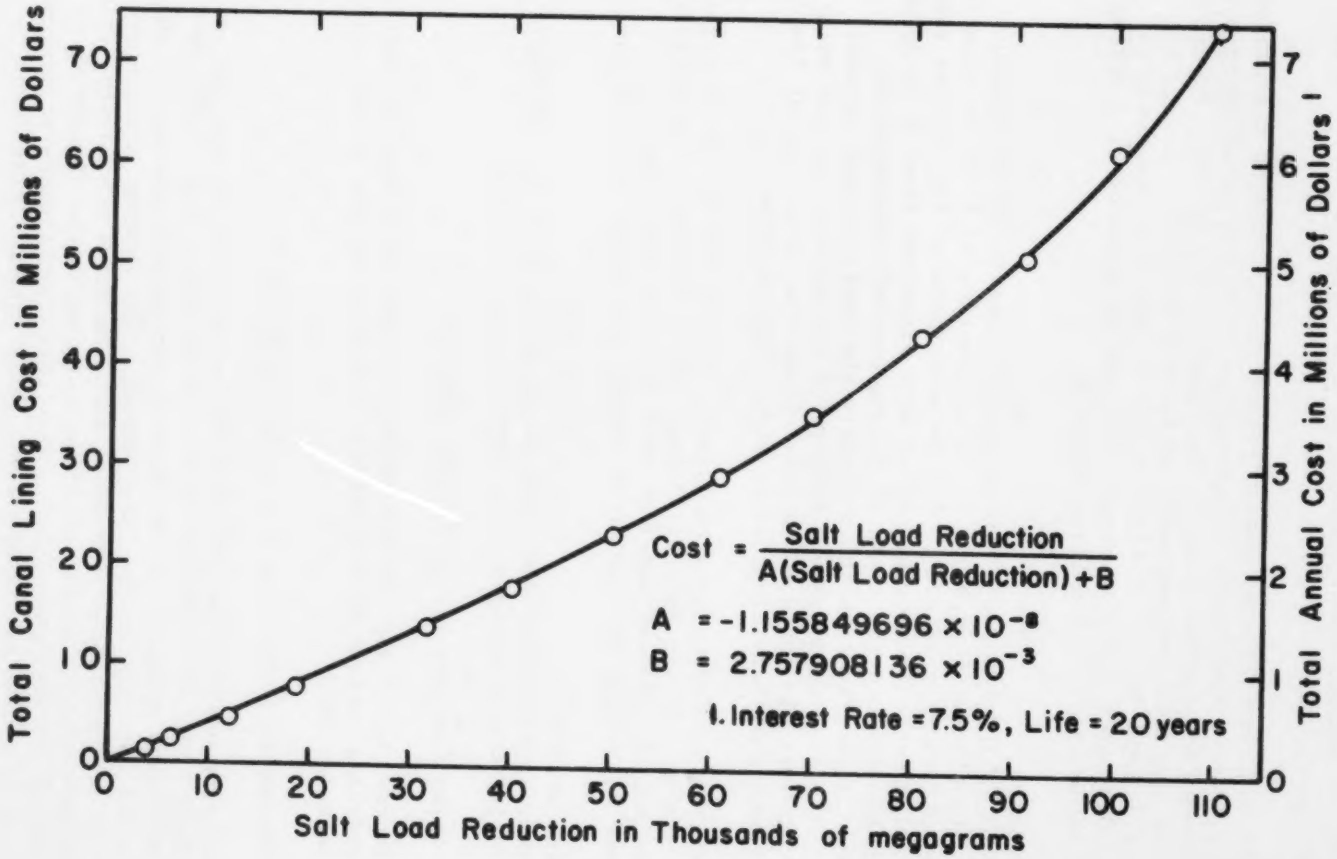

Figure C-17. Optimized canal lining cost-effectiveness function for the Grand Valley, Colorado.

Lining farm ditches--Many farmers have lined their farm conveyance networks to reduce seepage, maintenance and labor. The most common lining methods include a concrete slip form lining, a buried plastic membrane, compacted earth, or converting the ditches to plastic or aluminum pipelines. Each of these alternatives are relatively inexpensive, and have become accepted methods for improving on-farm water management.

In the Grand Valley, head ditch requirements are generally less than the capacity of the smallest standard ditch available through local contractors (12 inch bottom width, 1:1 side slope, slip form concrete). Assuming an average head ditch capactiy of 0.05 m^3/sec, the estimated unit cost of head ditch linings is $7.50/m. There are approximately 1.3 million meters of head ditches in the Grand Valley contributing an estimated 95,000 Mgm of salt to the river annually. If the head ditch linings are assumed to be 90 percent effective in controlling seepage over a 20 year period and the interest rate is 7.5 percent, the cost-effectiveness of head ditch linings is $11 Mgm and the limit of the measures effectiveness is 86,000 Mg/yr.

It is worth noting that head ditch linings are incorporated either directly or indirectly into nearly every other on-farm salinity control measures. If the surface irrigation system is automated, the head ditch is lined as part of the automation. In addition, a conversion to sprinkler or trickle irrigation would essentially eliminate head ditch seepage by replacing the conveyance network with pipe.

Automation of existing systems--There are two "operational" wastes which occur under furrow irrigation. The first, is the water percolating below the root zone and the second, is the runoff from the lower end of the field. Efforts to reduce each one is competitive; i.e., measures to minimize runoff will tend to increase deep percolation and vice versa. Since salinity is directly associated with deep percolation, local improvement programs will cause high runoff if not coupled with some system modification. In the Grand Valley, furrow irrigation uniformity and consequently efficiency can be substantially improved by three alternatives. First, irrigation scheduling should always be based on sampling at the lower end of the field so that the minimal intake opportunity (or irrigation set) can be determined. The flow in the furrow should be adjusted so that the time required for the flow to advance to the end of the field is about 25 percent of the minimal intake opportunity time. If these practices were implemented and strictly adhered to, local deep percolation volumes would be cut by more than 50 percent.

The second method for improving furrow irrigation uniformities and efficiencies is called cutback furrow irrigation. Under this method, the head ditch is sufficiently automated so that a large "wetting" furrow stream is introduced to advance the flow down the furrow and then the flow is "cutback" to a "soaking" flow rate to finish the irrigation. Cutback irrigation has one notable advantage over simply controlling the existing system--the field tailwater is greatly reduced. A system built in the Grand Valley and described by Evans (1977) achieved an application efficiency of 75%. The salt load reduction achieved by this system was 86,000 Mgm/yr due to seepage control in the field ditch and 46,000 Mgm/yr due to an 8% increase in efficiency. Using these figures as a guideline for efficiencies, and an annual cost of cutback furrow irrigation of $100/ha, the cost effectiveness was $18.94 Mgm/yr with an effectiveness limit of 132,000 Mgm/yr.

The final alternative for improving furrow irrigation is to utilize large furrow streams, collecting the excessive tailwater in a small reservoir, and then pumping this water back to the head of the field. This technology has also been demonstrated on one field in the Grand Valley. Because of the low value of water in Grand Valley, there are some difficulties in gaining farmer acceptance for this tailwater reuse system. However, this technology represents the most efficient furrow irrigation system when operated in terms of a known soil moisture deficit. A reasonable expectation of reuse system application efficiencies is 80%. Salinity control should be 86,000 Mgm/yr due to seepage control and 74,800 Mgm/yr due to a 13% increase in application efficiency. Using an annual cost for reuse systems of $147/ha, the cost-effectiveness of reuse systems is expressed as $22.85 Mgm/yr and limited in effectiveness to 160,800 Mgm/yr.

Sprinkler irrigation--A conversion from surface methods of irrigation to sprinkle irrigation systems by farmers in the Grand Valley would be highly beneficial in terms of efficient water use. Sprinkle irrigation systems, properly designed, installed and operated, have advantages both in terms of water quantity and quality. More uniform water application is generally possible on local types of soils, thereby minimizing deep percolation losses, and, of course, such a system should result in no tailwater runoff. The division of lands in the Valley are such that the most effective sprinkler system would be a sideroll or other portable system.

Sprinkler irrigation systems should be expected to be about 85% efficient when designed properly and operated in conjunction with an irrigation scheduling service. Consequently, the salinity control potential is comparable to well operated reuse systems described above. The annual costs of sprinkler irrigation systems are higher than those for furrow systems due to increased energy and maintenance costs. An annual figure of $250/ha is representative for the Grand Valley, indicating a cost-effectiveness of $32.89 Mgm/yr. The upper limit of salinity control for the sprinkle system is 168,000 Mgm/yr.

Trickle irrigation--Trickle irrigation is an irrigation method and would appear to have potential for orchard crops in the Grand Valley area. This method of irrigation has gained attention during recent years because of the potential for increasing yields, while decreasing water requirements and labor input.

For irrigating widely spaced crops, the cost of a correctly designed trickle irrigation system is relatively low in comparison to that for other solid-set or permanent irrigation systems. In orchards, the unit salinity control cost of a trickle irrigation system is comparable to that for a solid-set or permanent sprinkle system having the same level of automation. In addition, where clogging is not a problem and emitter line maintenance is minimal, operation and maintenance costs of the trickle irrigation system are usually quite low. However, in plantings of row crops or vines, where the average distance between emitter lines must be less than 3 meters, the cost of trickle irrigation is relatively high. When a trickle irrigation system is installed, there is usually a substantial need for technical assistance to insure that the plants are not being stressed and that a nutrient balance is being maintained.

The application efficiency for trickle irrigation systems, well designed and operated in conjunction with an irrigation scheduling program, can be 90-95%. The higher figure represents about a 9.9 Mgm/ha/yr reduction in salinity. Using an annual cost of $458/ha, the salinity cost-effectiveness is $46.32/Mgm/yr. The upper limit on trickle irrigation effectiveness, assuming it is applicable only to the orchard acreage in the valley is 28,500 Mg.

Optimizing the on-farm strategy--The cost-effectiveness of each on-farm salinity control practice along with its limits leads next to the evaluation of the optimal on-farm strategy. The cost-effectiveness relations detailed above are all linear as are the constraints which allows direct use of the linear programming algorithm. However, a subtle problem must be handled. The on-farm salinity control measures are not mutually exclusive as was the case for the canal linings. Thus, one other constraint must be imposed to insure that some measures are not implemented on the same fields. This is accomplished by dividing the total salt loading allocated to each measure by the per hectare effectiveness and then constraining the sum to be less than the total irrigated acreage.

The results of the Grand Valley optimization of on-farm salinity control measures are shown in Figure C-18. The figure shows the least cost on-farm cost-effectiveness curve fitted to data points corresponding to the individual solutions over the range of potential on-farm salinity control. For an example, suppose it was decided to reduce the farm related salinity contribution by 100,000 Mgm/yr. Figure C-18 indicates that this can be accomplished by an annual investment for improvements of $1.3 million.

Desalting--

In the previous section, the cost-effectiveness of the desalting alternative was expressed as a linear function of feedwater salinity. If the average feedwater salinity is assumed to be 5000 Mg/l for the Grand Valley, thereby allowing some mixing of surface and subsurface flows, the cost-effectiveness function for desalination alternative becomes:

$$\bar{C}_d = 5.0 \times 10^5 + 60.62\ S_1 \qquad (29)$$

where $\bar{C}_d$ = annual cost of reducing S_1 Mgm/yr.

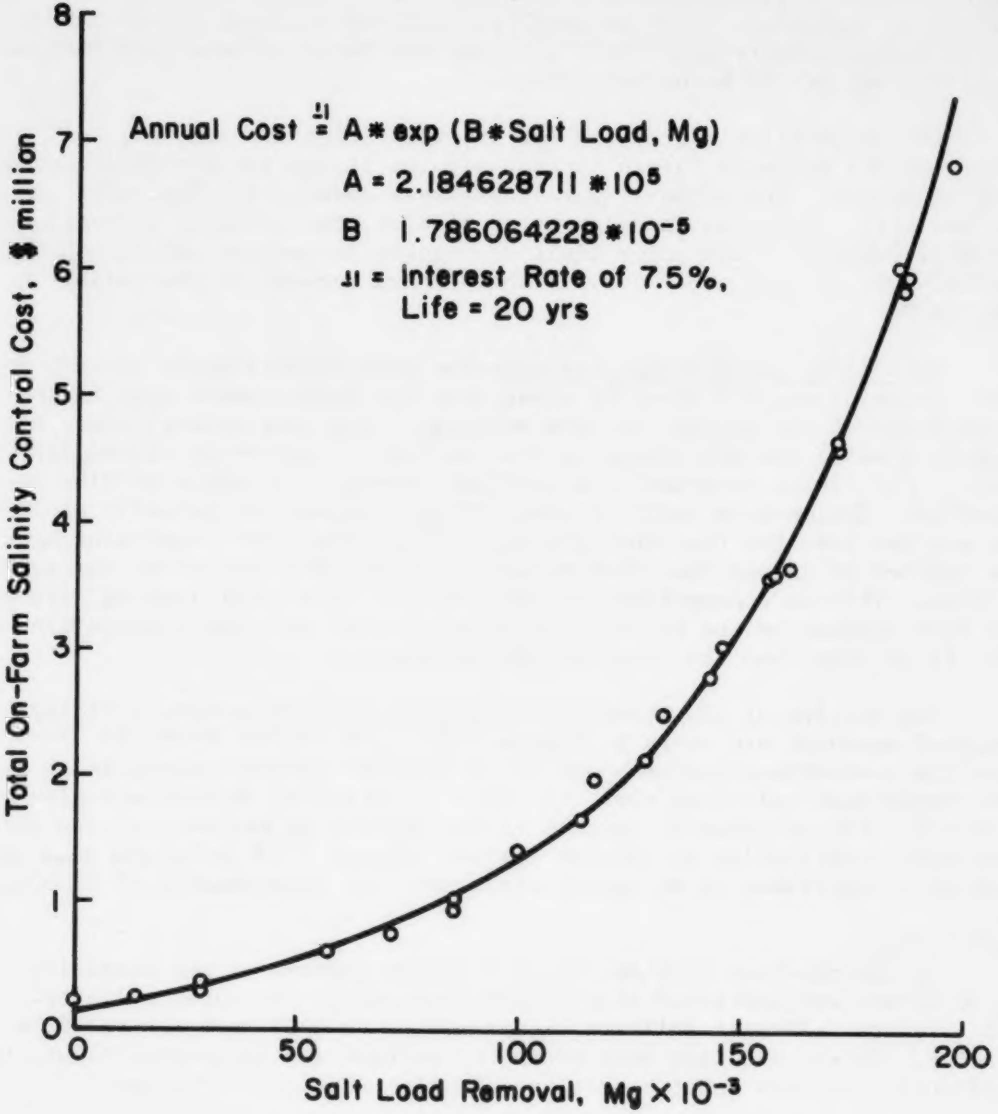

Figure C-18. Optimal on-farm salinity control cost-effectiveness curve.

AGGREGATING INDIVIDUAL BMP's

Once the most cost-effective strategies have been developed for the major salinity options for an area like the Grand Valley, the subsequent question is what is the most cost-effective valley-wide program. Obviously, this is an optimization of the optimal functions for canal and lateral lining, on-farm irrigation system improvement, and desalting of surface and subsurface return flows. The information to organize the optimization procedure is already available at this stage and the procedure can be undertaken with a standard operation research procedure.

The results of this final step are shown in Figure C-19. For instance, consider the consequences of a decision to reduce Grand Valley salinity by 400,000 Mgm/yr. Figure C-19 shows the annual cost of level of salinity reduction in Grand Valley to be $8.9 million/yr. Directly under the point at a cost of $6.0 million/yr is the boundary between the canal linings and the on-farm improvements. In other words, $2.19 million/yr is invested in canal linings under the optimal policy.

An examination of Figure C-19 shows that lateral linings are the first salinity control measure to be implemented and are a part of all other levels of control. As can be seen, the lateral lining cost for total reduction greater than 205,000 Mgm/yr is $1.5 million/yr. Consequently, it is now possible to determine from the graphs that the annual investment in on-farm improvements at the 400,000 Mgm/yr control level is $6.0 million minus $1.5 million or $4.5 million/yr.

SUMMARY

This case study on salinity control has been presented to illustrate the procedure for beginning with a salinity problem and finishing with an array of optimal practices for alleviating the problem. The Grand Valley in western Colorado is one of the most publicized salt problem areas because of its relationship to the problem in the Colorado River Basin.

The first step illustrated was the identification of specific causes of salt loading from an agricultural area. Field data collection and investigative studies are necessary programs in nearly any irrigated region because so little hydro-salinity data are reported. Once the various irrigation system components are identified as to their salinity impact, the potential solutions must be evaluated and demonstrated. Since not all will be found workable or acceptable to local irrigators, the list of potential measures will be generally reduced when implementation efforts are planned. Computer simulation along with experience in establishing the cost of each applicable salinity control allows the planner to formulate cost-effectiveness functions which can be used to compose alternatives to define the best strategy. A system of successive aggregation is demonstrated for taking individual project design alternatives and

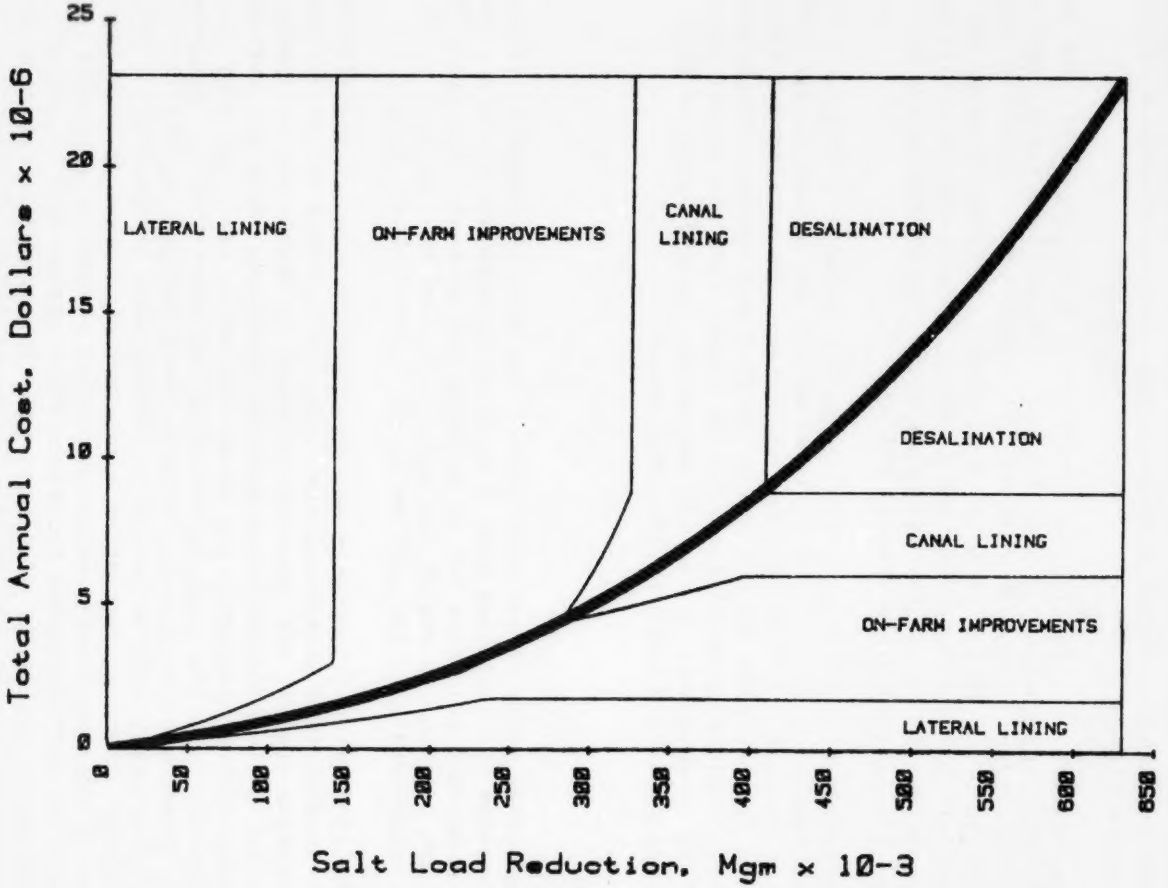

Figure C-19. Optimal Grand Valley salinity control cost-effectiveness relation and strategy.

organizing them into large scale plans for salinity control using operations research techniques to insure the resulting policy is one of least cost.

Those who deal with water and air quality improvement must be warned that the best solutions are rarely obvious. The array of alternatives should, therefore, be kept broad and evaluated regardless of how inefficient one might appear. A program of periodic reassessment is generally necessary to make the most effective communication links with each other, the research community, consulting organizations, administrative and legislative personnel, and the irrigation interests.

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APPENDIX D

NONPOINT SOURCE WATER QUALITY PROBLEMS RELATED TO ANIMAL AGRICULTURE

J.H. Martin, Jr. and R.C. Loehr

SECTION 1

INTRODUCTION

The potential of animal production activities to impair the quality of adjacent surface waters is well documented. Water quality problems including fish kills due to depressed dissolved oxygen levels and ammonia toxicity, accelerated rates of eutrophication, microbial contamination, and visual impairment have been directly linked to manures and other wastes associated with animal agriculture. Although not unrecognized, the impacts of animal production activities on water quality have, until recently, received little attention in water pollution control programs, being obscured by the magnitude of problems related to other sources, particularly point sources. Where identifiable, water quality problems associated with animal as well as other agricultural production activities were generally viewed as natural and uncontrollable. Over the past decade, however, a change in this traditional philosophy has occurred. Results of a number of studies have shown that pollutant discharges related to animal production activities can be substantial and that the resultant water quality impacts can be significant.

While the potential of animal agriculture to contribute to nonpoint source related water quality problems is clear, the magnitude and significance of pollutant discharges from individual production units can vary substantially. Difference in management practices which vary widely in animal agriculture can be a major factor contributing to this variability. Thus, it is not possible to rely solely on analyses of physical factors such as location, topography, precipitation, etc. to identify individual production units which require remedial measures such as implementation of best management practices to reduce or abate nonpoint pollutant discharges.

The purpose of this technical report is to provide guidance to those individuals responsible for the development and implementation of programs for the control of pollutants from agricultural nonpoint sources in addressing water quality problems associated with animal production activities.

This task appears to be best accomplished by providing an understanding of: (1) the nature and characteristics of water quality problems related to animal production activities; (2) the relative significance of the various physical sites from which pollutant discharges may occur; and (3) applicable control strategies.

SECTION 2

SCOPE OF NONPOINT SOURCE CONTROL ACTIVITIES FOR ANIMAL AGRICULTURE

Water pollutant discharges associated with animal production activities can occur from a variety of sources. Included are land used for manure disposal, pasture and rangeland, open confinement facilities, manure storages, milk houses and milking centers, and silos. With the exception of lands used for grazing and manure disposal, these potential sources of water pollutants could be considered to be point sources in that discrete, identifiable facilities, and in some situations conveyances, are involved. However, only concentrated animal feeding operations (feedlots) are designated point sources of water pollutants (U.S. Congress, 1972).

To assess needs, identify priorities, and develop implementation strategies for the control of nonpoint source discharges of pollutants from animal production units, the delineation of program scope is critical. If water quality problems associated with animal production activities are to be addressed successfully, point and nonpoint source control programs must interface but not overlap. This section has the following objectives:

1) To briefly review and discuss the established definitions of point and nonpoint sources of water pollutants,

2) To outline the nature and scope of the present point source control program for concentrated animal feeding operations (feedlots), and

3) To discuss the logic for including all other sources of water pollutants associated with animal agriculture in a nonpoint source control program.

POINT AND NONPOINT SOURCE DEFINITIONS

The terms point and nonpoint are formally used for the first time as descriptors of sources of water pollutants in the Federal Water Pollution Control Act Amendments of 1972 (the Act), (U.S. Congress, 1972). The term point source was defined as: ". . .any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged" (U.S. Congress, 1972).

Although the term nonpoint source was used extensively in the Act, it was never defined. Subsequently, it was defined by the U.S. Environmental Protection Agency as follows, "Nonpoint sources tend to be characterized by three elements. First, the pollutants are conveyed by water the source of which is uncontrolled by any person; that is, the water pollution results from precipitation, natural flooding or snowmelt. Second, the pollution itself is not traceable to a discrete, identifiable source such as a facility or industrial process. The fact that this runoff may be channelled into a ditch or drain before entering navigable waters does not, in and of itself, make natural surface runoff a discharge from a point source. Third, the control of nonpoint source water pollution is generally best achieved by planning and management techniques rather than by end-of-pipe treatment to remove pollutants. End-of-pipe treatment, designed to meet specified effluent limitations, is often inappropriate for pollution control for nonpoint sources. Instead, planning and management techniques control and abate the nonpoint pollution before it is created and thus effectively limit and prevent pollutants from reaching navigable waters."(Federal Register, 1976a). These planning and management techniques are approaches which have come to be known as best management practices (BMPs).

CONCENTRATED ANIMAL FEEDING OPERATIONS

Although concentrated animal feeding operations (feedlots) are designated to be point sources of water pollutants (U.S. Congress, 1972), all feedlots which generate water pollutant discharges are not subject to regulation under the National Pollutant Discharge Elimination System (NPDES) permit program. Under the present NPDES permit program (Federal Register, 1976b), pollutant discharges from feedlots with less than 1000 animal units may be either not identified or not considered to be point source discharges. Thus, concentrated animal feeding operations cannot be completely excluded from the scope of a nonpoint source control program designed to address water quality problems associated with animal agriculture.

In the development of the NPDES permit program for concentrated animal feeding operations, the term "animal feeding operation" was introduced and defined as, ". . .a lot or facility (other than an aquatic animal production facility) where the following conditions are met:

(i) Animals have been, are or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and

(ii) Crops, vegetation, forage growth or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." (Federal Register, 1976b).

However, not all animal feeding operations as defined above are considered to be potential point sources of water pollutants. The criteria for designating an animal feeding operation to be a concentrated animal feedng operation, and therefore a point source, are outlined in Table D-1.

TABLE D-1. NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM - BASIC STRUCTURE OF FEEDLOT PROGRAM (Federal Register, 1976b)

Feedlots with 1,000 or more animal units	Feedlots with less than 1,000 but with 300 or more animal units	Feedlots with less than 300 animal units
Permit required for feedlots with discharges[1] of pollutants.	Permit required if feedlot- 1. Discharges[1] pollutants through a man-made conveyance, or 2. Discharges[1] pollutants into waters passing through or coming into direct contact with animals in the confined area. Feedlots subject to case-by-case designation requiring an individual permit only after onsite inspection and notice to owner or operator.	No permit required (unless case-by-case designation as provided below). Case-by-case designation only if feedlot- 1. Discharges[1] pollutants through a man-made conveyance, or 2. Discharges[1] pollutants into waters passing through or coming into direct contact with animals in the confined area; and After onsite inspection, written notice is transmitted to the owner or operator.

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[1] Feedlot not subject to requirement to obtain permit if discharge occurs only in the event of a 25-yr, 24-hr storm.

The term "animal unit" is a standard unit of measurement based upon a feeder cow or steer representing one animal unit. The following numbers of various species of animals are equal to 1000 animal units:

1) 1000 slaughter and feeder cattle,
2) 700 mature dairy cattle including dry cows,
3) 2500 swine weighing over 25 kg (55 lb),
4) 500 horses,
5) 10,000 sheep or lambs,
6) 55,000 turkeys
7) 100,000 laying hens or broilers (if the facility has continuous overflow watering)
8) 30,000 laying hens or broilers (if the facility has a liquid manure handling system)
9) 5000 ducks (Federal Register, 1976b).

Those animal feeding operations designated to be point sources of pollutants are required to comply with the effluent guidelines and standards for feedlots point source category established by the U.S. Environmental Protection Agency (Federal Register, 1974). These guidelines and standards, which specify that no discharge of process wastewater pollutants is permitted with the exception of a 10-year, 24-hour rainfall event, are determined to be the best practicable control technology currently available. For best available technology economically achievable determined to be applicable to all new sources as of 1974 and is applicable to all sources by 1983, the exception to the no discharge requirement is a 25-year 24-hour rainfall event.

The no discharge effluent standard for animal feeding operations designated to be point sources of pollutants has resulted in the use of planning and management techniques, BMPs, such as runoff diversions and collection ponds rather than end-of-pipe treatment for control of discharges from these point sources. End-of-pipe treatment to meet specific stream standards has been shown in a number of studies to be neither practical nor economically feasible. The use of BMPs in these situations represents an extension of the basic philosophy that land-based disposal of wastes associated with animal agricultural activities represents the most suitable alternative.

SCOPE OF ANIMAL NONPOINT CONTROL ACTIVITIES

The foregoing discussion provides the underlying logic for including other sources of pollutants associated with animal production activities in the scope of a nonpoint source control program. **Although pollutant discharges from manure storages, milk houses and milking centers, and silos may occur via pipes or other man-made conveyances, end-of-pipe treatment techniques are clearly inappropriate. Thus, the question of whether or not these potential sources are point or nonpoint sources of pollutants is a moot issue. From a practical standpoint, inclusion of these potential sources as well as small animal feeding operations, less than 1000 animal units, in point source control programs is questionable due to limitation of resources for identification, monitoring, and enforcement.**

SECTION 3

POLLUTIONAL CHARACTERISTICS OF WASTE ASSOCIATED WITH ANIMAL AGRICULTURE

Typically, animal production activities occur in areas that include other land-based activities such as crop production, silviculture, etc. which also can generate nonpoint discharges of water pollutants. The determination of the effectiveness of best management practices (BMPs) in controlling specific water quality problems is dependent on the ability to distinguish between problems related to animal agriculture and other nonpoint sources. Knowledge of the characteristics and resultant water quality impacts of pollutants associated with animal production provides a basis to make this distinction.

The three principal sources of water pollutants associated with animal production are (1) manures, (2) milk house and milking center wastewaters, and (3) silage liquors. Although animal manures are the most visible of these sources, milk house and milking center wastewaters and silage liquors also can impair water quality. This section has the following objectives:

1) To provide an understanding of the origins and characteristics of these potential sources of water pollutants,

2) To discuss the nature of the water quality impacts of specific pollutant constituents, and

3) To outline a methodology which can be used to determine if an observed water quality problem is related to animal agriculture.

POLLUTIONAL CHARACTERISTICS

Animal Manures

Manures are significant potential sources of water pollutants due to the quantities produced. It has been estimated (Van Dyne and Gilbertson, 1978) that the dry matter content of manures voided annually by livestock and poultry in the United States exceeds 100 million tonnes annually. Manure produced by beef cattle on range and in feedlots accounts for over 50 percent of this amount (Table D-2). Although only a small fraction of the total quantity of animal manures produced enter surface waters, the impact on water quality can be substantial. Manures are concentrated sources of pollutants such as oxygen demanding compounds, nutrients, and microorganisms.

TABLE D-2. ESTIMATED U.S. MANURE PRODUCTION BY LIVESTOCK AND POULTRY, 1974 (Van Dyne and Gilbertson, 1978)

Specie	Manure, Dry Weight 1000 Tonnes/yr	% of Total
Beef cattle on range	47,268	46.7
Dairy cattle in feedlots	9,469	9.3
Dairy cattle	22,891	22.6
Swine	12,131	12.0
Sheep	3,447	3.4
Laying hens	3,064	3.0
Broilers	1,894	1.9
Turkeys	1,136	1.1
	101,300	100

It is difficult to quantitatively describe typical characteristics of nonpoint source discharges containing manurial constituents due to the many variables which affect the concentrations of specific pollutants. Runoff and seepage from animal manures will, however, contain many constituents the manures. Thus, knowledge of the pollutional characteristics of animal manures provides a sound basis for assessing the possible relationship between manures and an observed water quality problem.

Manures are the combined urinary and fecal excretions of livestock and poultry and are waste products of digestive processes. The principal constituents of manures are water, undigested and indigestible feedstuffs, end products of various metabolic processes, digestive fluids, and micro-organisms indigenous to the gastrointestinal tract. Varying quantities of wasted feed, bedding, and other materials such as soil may be mixed with the manure. Typical characteristics of livestock and poultry manures as excreted are summarized in Tables D-3 and D-4. In that manures are semi-solids, these characteristics are presented on a weight rather than a volume basis.

Manure runoff and seepage normally result in decreased and possibly zero dissolved oxygen levels, nutrient enhancement, microbial contamination, and possible ammonia toxicity to aquatic organisms in surface waters. Visual impairment due to manurial solids and pigments as well as noxious odors also can occur.

TABLE D-3. PHYSICAL AND CHEMICAL CHARACTERISTICS OF ANIMAL MANURES (American Society of Agricultural Engineers, 1979)

Parameter		Dairy Cow	Beef Feeder	Swine Feeder	Laying Hen	Broiler
Raw Manure* (RM). . . .	wt/day†	82	60	65	53	71
Total Solids (TS) . . .	%RM	12.7	11.6	9.2	25.2	25.2
Volatile Solids (VS) .	%TS	82.5	85	80	70	70
BOD_5	%TS	16.5	23	33	27	--
COD	%TS	88	95	95	90	--
BOD_5:COD	Ratio	0.19	0.24	0.35	0.29	--
Total Kjeldahl Nitrogen	%TS	3.9	4.9	7.5	5.4	6.8
Total Phosphorus, as P	%TS	0.7	1.6	2.5	2.1	1.5
Potassium, as K	%TS	2.6	3.6	4.9	2.3	2.1

*Feces and urine only
†Kg per 1000 kg liveweight

TABLE D-4. AVERAGE DENSITY OF INDICATOR ORGANISMS IN HUMAN AND DOMESTIC ANIMAL FECES

	Average Indicator Density, Per Gm.		Ratio
Animal	Fecal Coliforms*	Fecal Streptococci†	Coliform/ Streptococci
Man	1.3×10^7	3.0×10^6	4.3
Chicken	1.3×10^6	3.4×10^6	0.4
Cow	2.3×10^5	1.3×10^6	0.2
Pig	3.3×10^6	8.4×10^7	0.4

*Geldreich, 1966

†Kenner *et al.*, 1960

Depressed dissolved oxygen levels can be the result of both carbonaceous and nitrogenous compounds. The five-day biochemical oxygen demand (BOD_5) values reported for manures and runoff and seepage are not truly indicative of potential impact on dissolved oxygen levels in that the nitrogenous oxygen demand normally is not measured in the BOD_5 analysis. In addition, the BOD_5 determination is not an estimate of total carbonaceous oxygen demand but rather oxygen demand exerted by carbonaceous compounds which are readily available as microbial substances in five days. The chemical oxygen demand (COD) test includes carbonaceous compounds which cannot be utilized microbially as substrates and is, therefore, an overestimate of carbonaceous oxygen demand. The actual carbonaceous oxygen demand of animal manures liesbetween reported BOD_5 and COD values. Both parameters are, however, useful in indicating potential impact on the dissolved oxygen status of surface waters receiving nonpoint discharges related to animal manures. The carbonaceous oxygen-demanding materials in animal manures are present in both soluble and particulate forms. Thus, reduction or abatement of only the particulate fraction of manurial runoff and seepage may not totally alleviate water quality problems involving reduced dissolved oxygen concentrations.

As indicated (Table D-3), animal manures also can contribute nitrogen and phosphorus to surface waters resulting in the development of eutrophic conditions. Manurial nitrogen as excreted is in the form of proteinaceous compounds and urea or uric acid. Urea is excreted by mammals and uric acid by poultry. If ammonia, nitrite or nitrate compounds are present in fresh manures, their quantities are insignificant. These nitrogen compounds can be present in manure that has been partially degraded or oxidized.

The organic nitrogen compounds present in manures, particularly urea and uric acid, are readily available as substrates to a wide variety of aerobic and anaerobic, heterotrophic microorganisms. When manurial organic nitrogen compounds are degraded microbially, the nitrogen not utilized as a microbial nutrient is transformed into ammonia nitrogen. This process is termed ammonification and can occur under a wide variety of environmental conditions. Thus, ammonia nitrogen is a common constituent of manurial runoff and seepage and is a possible indicator of animal manure caused water quality problems.

Under aerobic conditions, ammonia nitrogen can be microbially oxidized to nitrate and nitrite nitrogen. The microorganisms primarily responsible for these transformations are the autotrophic species Nitrosomonas and Nitrobacter. The oxidation of ammonia to nitrate nitrogen is a two-step process termed nitrification which can be described as follows:

$$NH_4^{+} + 3/2\ O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^{-} + 2H^{+} + H_2O \qquad (1)$$

$$NO_2^{-} + 1/2\ O_2 \xrightarrow{\text{Nitrobacter}} NO_3^{-} \qquad (2)$$

The nitrification process is an oxygen demanding process. Stoichiometrically, 4.57 grams of oxygen are required for each gram of ammonia nitrogen oxidized to nitrate nitrogen. Thus, the nitrogenous oxygen demand exerted by organic and ammonia nitrogen in manurial nonpoint source discharges can be substantial (Table D-5).

The nitrification process can occur in terrestrial as well as aquatic environments. Thus, nitrate nitrogen also can be a constituent of manurial nonpoint pollutant discharges (Table D-6). Since nitrite and nitrate nitrogen are not exchangeable ions, they can be transported independently of particulate matter. Ammonia nitrogen is water soluble but also is an exchangeable cation. Thus, ammonia nitrogen transport can occur in association with or independently of soil and organic particles. Elevated concentrations of ammonia and nitrate nitrogen in surface waters are a potential indicator of nonpoint or point sources containing manure. Phosphorus in animal manures is present in both soluble and particulate forms. Available data (Table D-7) indicate that a substantial fraction of manurial phosphorus can be in the soluble form. In addition, the particulate phosphorus which is organically bound will be solubilized as organic matter degradation occurs. In the soluble form, phosphorus is readily available for transport via runoff. Elevated concentrations of both soluble and particulate phosphorus in surface streams can be indicative of runoff containing manure.

A wide variety of microorganisms are indigenous to the gastrointestinal tract of livestock and poultry and are excreted in fecal material. Nonpathogenic species, many of which are important to the digestive process, predominate. Although pathogenic species also may be present in manures, transmission of zoonotic diseases through contact with contaminated natural waters is rare. The presence of fecal coliforms and fecal streptococci in natural waters is, however, commonly used as an indicator of fecal contamination. Both of these groups of microorganisms are common inhabitants of the gastrointestinal tract of warm-blooded animals including man (Table D-4). Thus, they are utilized as organisms indicative of human or animal pollution. Geldreich (1966) suggested that the differences in the ratios of coliforms to streptococci for human and animal feces (Table D-4) may represent a method to distinguish between farm animal and human sources of water pollutants such as septic systems for human wastes. Thus, high ratio of fecal coliforms to fecal streptococci (greater than 4) in surface waters suggest contamination by human rather than animal sources. The use of fecal coliform to fecal streptococci ratios to distinguish between human and animal sources of fecal contamination should be used with caution, however, since differences in die-off rates can significantly alter this ratio.

Milk House and Milking Center Wastewaters

Following each milking of dairy cattle, milking equipment and facilities must be thoroughly cleaned to maintain milk quality. This results in the generation of a waste stream described as either milk house or milking center wastewater. On farms where cows are milked in the housing unit, the cleaning operation is limited to the milking equipment, the milk storage tank, and the milk house floor. The term milk house wastewater

TABLE D-5. COMPARISON OF BIOCHEMICAL AND NITROGENOUS OXYGEN DEMAND IN NONPOINT DISCHARGES CONTAINING MANURIAL CONSTITUENTS

Source Category	Biochemical Oxygen Demand (BOD_5)	Ammonia Nitrogen (NH_4-N)	Nitrogenous Oxygen Demand (NOD)*	Reference
Open confinement area runoff (mg/ℓ)	2395-12,750	33-774	151-3537	Wells et al., 1972
Stacked manure runoff and seepage (mg/ℓ)	9136-9398	1119-1559	5114-7125	Converse et al., 1975a
Manure disposal site runoff (mg/ℓ)	31.2-109.5	8.7-20.9	39.8-95.5	McCaskey et al., 1971

*NOD, mg/ℓ = NH_4-N, mg/ℓ x 4.57

TABLE D-6. COMPARISON OF AMMONIA AND NITRATE NITROGEN CONCENTRATIONS IN NONPOINT DISCHARGES CONTAINING MANURIAL CONSTITUENTS

Source	Ammonia Nitrogen (NH_4-N), mg/ℓ	Nitrate Nitrogen (NO_3-N), mg/ℓ	Reference
Open confinement area runoff	151-780	10-17.5	Gilbertson *et al.*, 1975
	--	2.1	Edwards *et al.*, 1972
	33-774	0-1270	Wells *et al.*, 1972
Manure disposal site runoff	25	3-5	Muck, 1975
	0.4-1.3	2-8	Long, 1979
	8.7-20.9	2.8-7.6	McCaskey *et al.*, 1971

TABLE D-7. AVERAGE VALUES FOR TOTAL AND SOLUBLE PHOSPHORUS IN LIQUID ANIMAL MANURES (Townshend *et al.*, 1969)

Species	Total Phosphorus, % of Total Solids	Soluble Phosphorus, % of Total Phosphorus
Swine	3.6	43
Poultry	2.3	18
Beef	1.4	54
Dairy	0.8	46

describes these wastewaters. These farms, typically, have herds of 50 cows or less. On larger farms, cows are more commonly milked in a specialized facility called a milking parlor which is adjacent to the milk house. This milk house-milking parlor combination is collectively described as a milking center. Since the milking parlor also is cleaned with water after each milking, milking center wastewater can contain a significant quantity of manure in addition to the constituents of milk house wastes.

Typical pollutional characteristics of milk house and milking center wastewaters are outlined in Table D-8 through D-11. Similar characteristics for the wastewaters have been reported by others (Loehr and Ruf, 1968 and Zall, 1972). These data show that the quantities of milk house and milking center wastewaters generated on dairy farms are not insignificant and can be sources of oxygen-demanding materials and nutrients if permitted to enter natural waters. The densities of fecal indicator organisms (Table D-11) in milking center wastewaters also should be noted. Although no data concerning indicator organism concentrations in milk house wastewaters is available, such concentrations should be less than those listed in Table D-11 since manure is not included in milking center wastewaters.

Silage Liquors

Ensiling is a fermentation process used extensively to preserve forage materials for use as feedstuffs for dairy and beef cattle. Although a variety of plant materials can be ensiled, most silages are made from grasses, legumes, corn, or sorghum. Silages made from grasses and legumes are often referred to as hay crop silages.

The preservation of ensiled materials results from the microbial production of lactic acid produced from plant carbohydrates in quantities that will reduce the pH of the ensiled mass to levels of 4.5 or less. At these pH levels, microbial activity of proteolytic and putrefactive organisms is inhibited. Although other acids including acetic, formic, andsuccinic as well as alcohols also are produced during the ensuing process, only lactic acid is produced in quantities sufficient to achieve the required low pH levels. This is due to the ability of species of the genus Lactobacillus to tolerate acidic conditions.

A common characteristic of the ensiling process is the generation of a liquid waste stream which is described by a variety of names including silo effluent, silo seepage, and silage liquor. The potential water quality impact of this waste stream is not widely recognized particularly in the United States. Thus, little information exists about the pollutional characteristics of silage liquors. The information which is available is summarized in Table D-12. The extremely high BOD_5 concentrations of silage liquors are noteworthy. A large fraction of this BOD_5 is attributable to the soluble organic compounds such as the organic acids and alcohols produced during the ensiling process. The forms in which nitrogen and phosphorus are present in silage liquors are unreported. Although the micorbial characteristics of silage liquors also are unreported, it is not likely that fecal indicator organisms would be present.

TABLE D-8. MILK HOUSE WASTEWATER CHARACTERISTICS (Martin,1979)

Parameter	mg/ℓ		Gm/Cow-Day	
	Farm A*	Farm B†	Farm A	Farm B
Total Solids	10,610	2,443	61.1	23.7
Volatile Solids	6,215	1,088	36.6	11.5
Biochemical Oxygen Demand, 5 Day	4,935	433	31.8	4.9
Chemical Oxygen Demand	14,870	1,474	94.4	16.0
Total Kjeldahl Nitrogen	368	58	2.23	0.59
Total Phosphorus	269	174	1.28	1.57
Volume, ℓ/Day	774	901	--	--
Volume, ℓ/Cow-Day	17.2	10.6	--	--

*45 Cows
†85 Cows

TABLE D-9. MILKING CENTER WASTEWATER CHARACTERISTICS (Bland, 1980)

Parameter, mg/ℓ	Farm A	Farm B	Farm C
Total Solids	3830	6460	1200
Volatile Solids	2030	4522	588
Suspended Solids	1160	3870	290
Biochemical Oxygen Demand, 5-Day	2290	2270	370
Chemical Oxygen Demand	4060	6100	880
Total Kjeldahl Nitrogen	280	560	60
Ammonia Nitrogen	189	250	29
Total Phosphorus	135	79	44
Filterable Orthophosphate	101	36	35
Number of Cows, Av.	58	125	64
Volume, ℓ/Day	1020	1250	2010

TABLE D-10. QUANTITIES OF POLLUTANTS IN MILKING CENTER WASTEWATERS (Bland,1980)

Parameter, Gm/Cow-Day	Farm A	Farm B	Farm C
Total Solids	67	65	38
Volatile Solids	36	45	18
Suspended Solids	20	38	9
Biochemical Oxygen Demand, 5-Day	41	22	11
Chemical Oxygen Demand	70	61	30
Total Kjeldahl Nitrogen	4.9	5.6	1.8
Total Phosphorus	2.5	0.8	1.3
Volume, ℓ/Cow-Day	18	10	32

TABLE D-11. AVERAGE DENSITY OF INDICATOR ORGANISMS IN MILKING CENTER WASTEWATERS (Bland, 1980)

	Average Indicator Density, Per 100 mg/ℓ		Ratio
Farm	Fecal Coliform	Fecal Streptococci	Coliform ^ Streptococci
A	2.2×10^6	5.9×10^5	3.7
B	1.9×10^7	3.0×10^7	0.6
C	2.3×10^7	2.0×10^7	1.2

TABLE D-12. POLLUTIONAL CHARACTERISTICS OF SILAGE LIQUORS (mg/1)

Source	Biochemical Oxygen Demand, 5 Day (BOD_5)	Nitrogen (Total as N)	Phosphorus (as P)
Anon., 1963	12,550 - 66,400	1000-5000	61-613
Little, 1966	30,000 - 60,000	-	-
Berryman, 1970	-	2300	44-1311

The volume of silage liquors generated during the ensiling process is highly variable, with reported values ranging from virtually nil to quantities in excess of 400 ℓ per tonne of material ensiled for conventional tower silos. Thus, volume of silage liquor discharges may be substantial. For example, the volume of silage liquor discharged from a 6.1 m x 18.3 m tower silo can exceed 151,000 ℓ. A silo having the dimensions noted above has a capacity of approximately 360 tonnes.

Due to greater internal pressures, the quantity of silage liquor discharged from a tower silo normally exceeds that from a horizontal or bunker silo. An exception is an uncovered horizontal silo where precipitation infiltration can result in a substantial silage liquor discharge. Silage liquor discharges from controlled atmosphere silos is nil when these structures are operated properly.

Normally, silage liquor discharges are limited to a six-week period following silo filling with maximum flow occurring during the first two weeks. These discharges are seasonal in nature being limited to summer and early fall months. Typically, no effort is made to contain or collect silage liquors with disposal occurring in an uncontrolled manner. Water quality impacts caused by silage liquors occur in the summer and early fall and primarily result in decreased dissolved oxygen levels.

WATER QUALITY IMPACTS

From the previous discussion it can be seen that the pollutional characteristics and therefore the potential water quality impacts of the principal sources of water pollutants associated with animal agriculture are similar. A number of these pollutional characteristics can be used to distinguish between water quality problems associated with animal production activities and those related to other nonpoint sources such as cropland runoff. The relative water quality impacts of animal agriculture and cropland nonpoint sources (Table D-13) indicate a number of differences.

One probable impact common to all potential sources of water pollutants associated with animal production is decreased dissolved oxygen concentrations. These discharges also will be reflected by increases in BOD_5 and COD concentrations in a stream. Although nitrogen enrichment can result from nonpoint source discharges from a variety of land-based activities, increases in ammonia nitrogen concentrations are most likely to be associated with animal production activities. Conversely, nitrate nitrogen is less useful as a parameter for source identification in that nitrate nitrogen is a common constituent of cropland runoff. **The presence of fecal coliform and fecal streptococci indicator organisms in increased concentrations also suggests that animals or manures could be a source of the problem.** These organisms, however, may not be present in increased concentrations in situations where milk house wastewaters or silage liquors are the principal nonpoint pollutant sources.

In the analysis of available water quality data to determine if an observed water quality problem is related to animal agriculture, placing total emphasis on one water quality characteristic should be avoided. Rather, a combination of water quality characteristics should be examined. Results of a study by Dornbush et al., 1974 provide an excellent example of the need to consider more than one water quality characteristic. Although the use of fecal indicator organisms to indicate manurial contamination is fundamentally sound, these organisms may be present in runoff from sites not recently used for animal confinement or manure disposal (Table D-14). Although the observed fecal indicator organism concentrations suggest the presence of animal manures, neither BOD_5, COD, or ammonia nitrogen concentrations would support this conclusion. The combination of parameters in this example indicate that the source is more likely to be runoff from land on which manure might have been added at one time. This demonstrates the need for comprehensive water quality characterization in problem areas to provide a sound basis for source determination analyses.

TABLE D-13. PROBABLE WATER QUALITY IMPACTS OF ANIMAL AGRICULTURE AND CROPLAND RUNOFF NONPOINT DISCHARGES

Parameter	Animal Manures	Milk House Wastewaters	Milking Center Wastewaters	Silage Liquors	Cropland Runoff
Dissolved Oxygen	-	-	-	-	0
Biochemical Oxygen Demand	+	+	+	+	0
Chemical Oxygen Demand	+	+	+	+	0
Total Nitrogen	+	+	+	+	+
Ammonia Nitrogen	+	+	+	+	0
Nitrate Nitrogen	*	0	0	0	+
Total Phosphorus	+	+	+	+	+
Soluble Phosphorus	+	+	+	+	+
Fecal Coliforms and Streptococci	+	0	+	0	0
Sediment	0	0	0	0	+

- Decrease in concentration when compared to background conditions
+ Increase in concentration when compared to background conditions
0 No significant impact
* Possible increase depending upon prior oxidation of manures before runoff occurs

TABLE D-14. POLLUTIONAL CHARACTERISTICS OF RAINFALL AND SNOWMELT RUNOFF FROM CROPLAND AND IDLE PLOWED LAND (Dornbush *et al.*, 1974)

		Concentration, mg/ℓ				Counts/100 ml		
Land Use	Runoff Type	Biochemical Oxygen Demand	Chemical Oxygen Demand	Ammonia Nitrogen	Nitrate Nitrogen	Fecal Coliforms	Fecal Streptococci	FC/FS, Ratio
Corn and Oats	Rainfall	8	466	0.29	0.83	13,971	106,671	0.131
	Snowmelt	11	56	0.50	0.83	1,411	35,091	0.040
Idle Plowed Land	Rainfall	-	39	0.13	0.90	9,168	72,548	0.126
	Snowmelt	-	60	-	0.64	2,592	6,727	0.385

SECTION 4

PHYSICAL SOURCES OF POLLUTANTS ASSOCIATED WITH ANIMAL PRODUCTION ACTIVITIES

Once it has been decided that an observed water quality problem is related to animal production activities, it is then necessary to identify the physical source or sources of the responsible pollutant discharges before appropriate candidate best management practices (BMPs) can be selected and evaluated. These physical sources are the sites from which nonpoint pollutant discharges can occur. This represents one of the most challenging steps in reducing nonpoint water quality problems associated with animal agriculture due to the number of possible sources:

1) Confinement facilities,
2) Land used for manure disposal,
3) Manure storage facilities,
4) Pasture and rangeland,
5) Silos, and
6) Milk houses and milking centers.

This section will provide direction in identifying the most potentially significant nonpoint sources associated with individual animal production units.

CONFINEMENT FACILITIES

Confined production facilities are used extensively in animal agriculture with the exception of the cow-calf and stocker segments of the beef cattle industry where unconfined production systems utilizing pasture and range predominate. An animal confinement facility is one in which an insignificant fraction, commonly none, of the confined animal's nutrient requirements are satisfied by grazing. An important difference between confined and unconfined animal production systems is that manure produced in confinement facilities requires collection and disposal. Estimates of the distribution of confined and unconfined production systems in the dairy, beef, swine, and poultry industries are outlined in Table D-15.

Confinement facilities used in animal agriculture are of three general types: (1) totally enclosed, (2) partially enclosed, and (3) open. In partially enclosed facilities, animals have access to uncovered areas. Both partially enclosed and open confinement facilities are potential nonpoint pollutant sources due to opportunities for manurial contaminated runoff to enter surface waters. Totally enclosed facilities themselves are not

Table D-15. LIVESTOCK AND POULTRY PRODUCTION MANAGEMENT SYSTEMS (Gilbertson et al., 1979)

Management Systems	Areas of the United States %			
	Northeast and Lake States	Southeast, Delta and Southern Plains	Mountains and Pacific	Corn Belt, Northern Plains, and Appalachian
DAIRY				
Stanchion	63	7	4	22
Loose housing	6	38	14	34
Free stall	26	22	35	41
Unpaved lot, limited housing	5	33	47	3
		West of 98th Meridan	East of 98th Meridan	
BEEF				
Breeding Stock				
-pasture		90	90	
-other		10	10	
Feeders				
-outdoor, unpaved lot without shelter		85	56	
-outdoor, unpaved lot with shelter		4	31	
-outdoor, paved lot with/without shelter		11	13	
		Major Producing States	All Other States	
SWINE				
Pasture		25	50	
Paved Lot		17	5	
Unpaved lot		41	40	
Confined housing		17	5	
		All Regions		
LAYERS				
Caged with dry manure-holding system		70		
Caged with liquid pits		10		
Loose housing with litter		20		
BROILERS				
Loose housing with litter		100		

potential nonpoint sources due to the absence of opporunities for contact between manures and elements of the hydrologic cycle. However, the manure disposal sites associated with totally enclosed confinement facilities can be sources of nonpoint pollutant discharges.

Poultry

Totally enclosed production facilities are used almost exclusively in the production of eggs and meat-type chickens such as broilers. Cage systems are used extensively for egg production with only a small fraction of U.S. egg production occurring in loose housing-litter systems. In contrast, loose housing-litter systems predominate in the broiler industry and are used for breeder flocks of both egg and meat-type birds.

Dairy

All three types of confinement facilities are used in the dairy industry. Stanchions, free stall, and loose housing systems can be operated as either totally or partially enclosed confinement units at the option of the producer. When operated as partially enclosed units, animals have controlled or uncontrolled access to a paved or unpaved barnyard or exercise lot which can be a potential nonpoint pollutant source. Where pastures are utilized, barnyards and exercise lots may be used as milking parlor holding areas with some resultant manure accumulation. In situations where barnyards and exercise lots are located immediately adjacent to streams, the stream may be used directly as a source of drinking water providing a second mechanism for water quality degradation. Although open confinement systems can be considered to be potential nonpoint sources of pollutants, systems with flushing systems for manure removal are an exception. Containment of the flush water also should prevent runoff discharges resulting from precipitation and snowmelt.

Beef

Most beef cattle are finished in confinement facilities. However, unconfined animal production systems are used almost exclusively in the cow-calf and stocker segments of the beef cattle industry. Typically, young cattle from cow-calf and stocker operations are fattened (finished) on high energy rations in confinement facilities known as feedlots. The large commercial feedlots located primarily in the west-central and south-western states have been the cause of significant surface water pollution in the past decade. Commercial feedlots which typically have capacities exceeding 1000 animal units are considered to be point rather than nonpoint sources of pollutants. In contrast, farmer-feeder finishing operations commonly involve feedlots with less than 1000 and often less than 300 animal units. These smaller beef cattle feedlots are common in both the midwest and upper midwest and also may be encountered in other geographical areas. Although totally enclosed feedlots are increasing in number particularly in the upper midwest due to improved feed efficiency, open and partially enclosed feedlots are more common. Even though these small concentrated feeding operations can be designated as point sources in specific situations, these facilities are not likely to be considered as point sources in state regulatory programs. They, therefore, should be included in nonpoint source control programs.

Swine

All three of the general types of animal confinement facilities are used in the swine industry. Unpaved open lots are the most common followed by partially enclosed paved lots and totally enclosed facilities. Although totally enclosed facilities are used for fattening feeder pigs, their use for farrowing operations is more common. Both paved and unpaved lots constitute potential nonpoint sources due to the presence of manure accumulations. Location of unpaved lots for swine adjacent to streams to provide a source of drinking water and relief from heat has not been uncommon. This provides an additional mechanism for water quality degradation.

Runoff Characteristics

The pollutional characteristics of runoff from open areas of partially enclosed animal confinement facilities are highly variable due to factors such as the type of surface (paved or unpaved), stocking density, quantity of accumulated manure, antecedent moisture conditions, amount and intensity of precipitation, and temperature. Data for commercial beef feedlots summarized by Clark *et al*. (1975) (Table D-16) and observations from the study of a small beef feeding operation (barnlot) reported by Edwards *et al*. (1972) (Table D-17) are indicative of the variability in runoff characteristics which can be expected. Gilbertson *et al*. (1975) have shown that the type of runoff, precipitation vs snowmelt, *also* significantly affects runoff characteristics (Table D-18). Thus, it cannot be realistically assumed that all open confinement facilities are equivalent in terms of nonpoint pollution potential.

TABLE D-16. CHARACTERISTICS OF BEEF CATTLE FEEDLOT* RUNOFF, AVERAGE VALUES (Clark *et al.*, 1975)

Location	Total Solids, mg/ℓ	Electrical Conductivity µmho/cm	Chemical Oxygen Demand mg/ℓ	Total Nitrogen mg/ℓ	Total Phosphorus mg/ℓ
Bellville, TX.	9,000	--	4,000	9,000	85
Bushland, TX.	15,000	8.4	15,700	15,300	205
Ft. Collins, CO.	17,500	8.6	17,800	17,500	93
McKinney, TX.	11,429	6.7	7,210	11,400	69
Mead, NE.	15,200	3.2	3,100	15,200	300
Pratt, KS.	7,500	5.4	5,000	7,500	50
Sioux Falls, S.D.	2,986	--	2,160	3,000	47

* Unpaved except around feedbunks and water troughs

TABLE D-17. SEASONAL VARIATION IN NUTRIENT CONCENTRATION OF BARNLOT RUNOFF (Edwards *et al.*, 1972)

Month	Mean Concentration, mg/ℓ			
	Total Nitrogen	Nitrate Nitrogen	Total Phosphorus	Potassium
January	68.2	1.7	8.6	326
February	60.8	1.9	6.7	326
March	47.8	1.3	5.0	350
April	32.9	1.2	4.0	195
May	30.9	0.5	4.7	290
June	14.9	1.1	3.5	172
July	14.7	4.4	3.1	131
August	8.6	5.8	1.4	122
September	30.4	1.6	13.9	201
October	37.3	2.6	10.8	189
November	29.6	2.0	7.2	191
December	40.7	0.9	5.8	158
Yearly Average	34.7	2.1	6.2	221

TABLE D-18. DIFFERENCES IN PHYSICAL AND CHEMICAL CHARACTERISTICS BETWEEN RAINFALL AND SNOWMELT RUNOFF FROM BEEF CATTLE FEEDLOTS* (Gilbertson *et al.*, 1975)

Parameter	Snowmelt Runoff	Rainfall Runoff
Total Solids (TS), %	6.3	7.0
Volatile Solids, % of TS	50.6	42.1
Fixed Solids, % of TS	49.4	57.9
Chemical Oxygen Demand, mg/ℓ	41,000	3,100
Total Kjeldahl Nitrogen, mg/ℓ	2,105	854
Ammonia Nitrogen, mg/ℓ	780	151
Nitrate Nitrogen, mg/ℓ	17.5	10
Total Phosphorus, as P, mg/ℓ	292	300
pH	6.3	7.0

* Unpaved; 18.6 m^2/animal

LAND USED FOR MANURE DISPOSAL

Manure collection and disposal is a requirement common to all confined animal production facilities. Sites used for manure disposal can be sources of nonpoint pollutant discharges resulting in water quality impacts such as those (Table D-19) observed by Janzen et al. (1974). The actual significance of specific sites is , however, dependent on a number of variables. In addition to the general factors affecting runoff quality such as slope, degree of vegtative cover, etc., timing and rate of manure application also are important.

Frequency of manure disposal is highly variable, ranging from daily to once per year depending on the availability and capacity of manure storage facilities. Daily manure spreading is most commonly practiced in the dairy industry, particularly where confinement and free stall stystems are used. Although it is not typical, some poultry producers also spread manure daily as an odor control measure. In nothern areas, daily spreading results in applications of manure to frozen and snow-covered fields. Results of studies such as that by Minshall et al. (1970) have shown that winter applications of manures can significantly increase nutrient losses (Table D-20). Studies by Converse et al. (1975b) and Klausner et al. (1976) have shown that nutrient losses from sites receiving winter manure applications are highly variable depending on the amount of winter precipitation producing runoff and the timing of manure applications with respect to runoff events.

When manure is stored, six months is a common system design value resulting in two intensified periods of manure disposal, commonly early spring and late fall. When 12-month storage is available, manure disposal normally occurs in the fall. Thus, there may or may not be a seasonal pattern of nonpoint pollutant discharges from manure disposal sites.

Normally, pastures and cropland are utilized for manure disposal with the objective of plant nutrient recovery. Although escalating chemical fertilizer prices have resulted in the more careful use of manures as sources of plant nutrients, application rates are not always matched to agronomic need. Nonproductive land also may be used for manure disposal, particularly where all feedstuffs are purchased or when productive land is not available. Many large poultry farms and commercial feedlots purchase all feedstuffs resulting in the use of nonproductive land for manure disposal. Under these conditions, application rates which are significantly higher than those used for productive land are not uncommon. Thus, the potential for adverse water quality impact is substantially increased when nonproductive land is used for manure disposal.

MANURE STORAGE FACILITIES

Manure storage facilities are not, in general, potential sources of water pollutant discharges. Manure stacking systems are the one notable exception. Open facilities for storage of liquid manures such as earthen lagoons are totally confined and are potential sources of water pollutants only if management practices do not provide for containment of incident pre-

TABLE D-19. WATER QUALITY IMPACTS OF RUNOFF FROM LAND USED FOR DAIRY CATTLE MANURE DISPOSAL (Janzen *et al*., 1974)

Parameter, mg/ℓ	Solid Manure Applied to Site*			Liquid Manure Applied to Site*		
	A†	B‡	C§	A†	B‡	C§
Biochemical Oxygen Demand, 5-Day	16.2	26.6	14.8	9.4	23.9	10.5
Chemical Oxygen Demand	24.7	37.9	21.8	12.0	28.8	16.1
Nitrate Nitrogen	2.3	3.9	2.8	2.2	2.2	2.1
Phosphate (PO_4)	2.4	3.6	2.9	2.0	2.5	1.9
Dissolved Oxygen	7.5	7.2	7.1	9.7	9.3	10.0
E. coli, cnts/100 ml.	15×10^3	30×10^3	20×10^3	9×10^3	50×10^3	25×10^3
Number of observations	74	61	74	13	13	13

* Application rates not reported
† 50-600 m upstream
‡ adjacent to the disposal site
§ 50-600 m downstream

TABLE D-20. NUTRIENT LOSSES FROM WINTER VERSES SUMMER SPREADING OF DAIRY CATTLE MANURE (Minshall et al., 1970)

Manure Type	Time of Application*	Nutrient	Average Application Rate, kg/ha†	Average Nutrient Loss, kg/ha†		
				Winter	Summer	Annual
None	--	Nitrogen	--	0.74	1.02	1.76
		Phosphorus	--	0.13	0.40	0.53
		Potassium	--	1.21	1.45	2.66
Fresh	Jan-Feb	Nitrogen	121	4.35	0.77	5.12
		Phosphorus	42	0.95	0.24	1.19
		Potassium	116	2.48	0.68	13.52
Fermented	May	Nitrogen	115	0.87	0.76	1.63
		Phosphorus	42	0.14	0.19	0.33
		Potassium	99	1.72	0.82	2.54
Fermented	May	Nitrogen	95	0.72	0.73	1.45
		Phosphorus	36	0.15	0.24	0.39
		Potassium	113	1.67	1.12	2.79

* Manure applied once per year at the rate of 33.6 tonnes/ha

† Three year averages

cipitation and runoff or if lagoon sides and bottoms are not properly sealed. Pollutant discharges from liquid or slurry manure storage facilities are not common.

The use of stacking systems for manure storage is limited to the dairy industry and generally to manure produced in confinement stall housing units where high amounts of bedding are used. Where stacking sites are not enclosed, both runoff and seepage can be significant sources of water pollutants (Table D-5). Although runoff discharges do not occur from enclosed stacking facilities, seepage losses may be greater during summer months due to reduced evaporation (Tenpas et al., 1972).

PASTURE AND RANGELAND

Pastures and rangeland are used extensively in the cow-calf and stocker segments of the beef cattle industry. Pastures also are used in combination with confinement facilities for dairy cattle and for swine. Although the terms pasture and range have different meanings, the distinction between the two terms is not always clear-cut. In general, the term range refers to naturally vegetated areas of relatively low productivity whereas plant species in pastures are usually introduced and maintained. Due to higher levels of plant productivity, animal stocking rates for pastures are usually higher than those for rangeland.

The principal areas of concern relative to water quality impacts of pastures and rangeland are where animals congregate, where they have access to streams, and wintering sites where supplemental feed is provided (Robbins, 1978). Grazing livestock have the tendency to congregate in shaded and protected areas and adjacent to watering troughs, salt sources, etc. In addition to increased manure accumulation, soil compaction and destruction of vegetative cover occurs in these areas. This results in increases in both runoff quantity and pollutant concentrations as compared to other areas of pasture and range. Soil erosion rates also can be increased. Characteristics of rainfall and snowmelt runoff from grasslands used as grazing sites and from cropland not used for manure disposal (Table D-21) show comparable pollutant concentrations. Results of a study by Sewall and Alphin, 1972 (Table D-22) illustrate the potential water quality impacts which can result from heavily grazed pastures when compared to forested watersheds.

Livestock on pasture and range frequently have access to streams traversing these areas. In many instances, the stream is the only source of water for the grazing animals. This access results in the direct deposition of feces and urine into surface waters and can destabilize streambanks, increasing soil erosion. Although the potential for water quality impairment is clear, the actual impact of grazing animals entering streams is unclear. In studies that have attempted to look at pollution from pasture and range, (Robbins et al., 1971 and Milne, 1976), the impacts of livestock entering streams and runoff discharges of pollutants from adjacent land have not been separated.

TABLE D-21. POLLUTIONAL CHARACTERISTICS OF RAINFALL AND SNOWMELT RUNOFF FROM PASTURES AND CROPLAND (Dornbush et al., 1974)

			Concentrations, mg/ℓ					Counts/100 ml x 10^2		
	Runoff Type	BOD	COD	TKN	NH_4-N	NO_3-N	Total Phosphorus	Fecal Coliforms	Fecal Streptococci	FC/FS, Ratio
Cropland, Corn and Oats	Rainfall	8	11	2.4	0.29	0.83	1.70	140	107	0.131
	Snowmelt	11	56	2.0	0.50	0.83	0.53	14	351	0.40
Alfalfa and Bromegrass used as Fall Pasture*	Rainfall‡	--	22	0.8	0.20	0.30	0.30	7.9	161	0.005
	Snowmelt	16	71	3.2	1.49	0.74	0.74	25	92	0.272
Grassland-Summer Pasture†	Rainfall‡	--	49	1.7	0.30	0.35	0.35	828	545	1.519
	Snowmelt	--	69	3.4	--	0.89	0.67	20	22	0.928

* Unspecified time period
† 3-4 weeks
‡ Includes time periods when animals were present

TABLE D-22. WATER QUALITY IMPACTS OF ANIMAL PRODUCTION ACTIVITIES (Sewell and Alphin, 1972)

	Concentration, mg/ℓ			cnts/100 ml.	
Source	Biochemical Oxygen Demand, 5 Day	Nitrate-Nitrogen	Ortho-Phosphate	Total Coliform	Fecal Coliform
Forested Watershed	2.5	0.05	0.05	1.5×10^3	--
Forested Watershed	2.6	0.04	0.08	1.7×10^3	--
Heavily Grazed Pasture*	13.8	4.5	7.1	330×10^3	41×10^3
Heavily Grazed Pasture*	16.7	5.1	1.2	158×10^3	64×10^3

*Dairy Cattle

In areas where dormant vegetation is not adequate for animal maintenance, winter pasture or range with supplemental feeding of hay and forages is used in cow-calf and stocker operations. Animal densities in wintering areas are significantly higher than those typical of grazing operations resulting in more concentrated accumulations of manure and increased concentrations of pollutants in rainfall and snowmelt runoff (Table D-23). Results of a study of the water quality impacts of a livestock wintering operation by Milne (1976) showed no significant impact on chemical water quality parameters. Counts of fecal coliforms and fecal streptococci, however, increased significantly at the location of greater livestock activity as compared to upstream counts. The contradictory results of these two studies are indicative of the site-specific nature of pasture and rangeland runoff water quality impacts.

SILOS, MILK HOUSES, AND MILKING CENTERS

Silages are widely used as feedstuffs for dairy cattle and also may be used as roughage for feeder steers. Therefore, the use of silos is limited to dairy and beef cattle production. Silage liquor discharges (Table D-12) are normally limited to the first six to eight weeks of the ensiling process. In that silages are made only in the summer and early fall, water quality problems associated with silage liquors are limited to this period of the year.

Both milk houses and milking center wastewaters (Tables D 8-11) are generated daily through the year. These wastewaters can be discharges directly to streams, to roadside ditches, or to unmanaged land disposal sites. When the land disposal sites are not managed properly, surface runoff and seepage can transport the pollutional constituents of the applied wastewaters to adjacent surface waters.

SUMMARY

The potential significance of the six sources of nonpoint pollutant discharges associated with animal production activities are summarized in Table D-24. Manure disposal sites are potential sources of water pollutants common to all segments of animal agriculture. The dairy farms have the greatest number of potential pollutant sources and poultry farms have the least.

The actual significance of the possible nonpoint sources of water pollutants discussed in this section is dependent on more than the presence of animals or manure. Factors such as proximity to surface waters and management practices also can have a significant influence on the potential water quality impacts and the need to implement BMPs.

TABLE D-23. IMPACT OF SUMMER GRAZING AND WINTER FEEDING OF BEEF CATTLE ON RUNOFF WATER QUALITY* (Chichester _et al_., 1979)

Period	Organic Carbon, mg/ℓ		Organic Nitrogen mg/ℓ		Mineral Nitrogen† mg/ℓ		Total Phosphorus mg/ℓ	
	Summer Grazed	Winter Feeding	Summer Grazed	Winter Feeding	Summer Grazed	Winter Feeding	Summer Grazed	Winter Feeding
May - Oct 1974	38.8	21.2	3.3	0.6	2.9	1.8	1.3	1.8
Nov - Apr 1975	35.8	85.4	1.2	4.2	1.5	2.2	0.6	1.1
May - Oct 1975	22.2	42.1	0.6	2.4	0.7	2.7	1.3	0.6
Nov - Apr 1976	8.6	67.0	1.4	12.6	1.0	9.5	0.3	1.4
Average	46.4	53.9	1.6	5.0	1.5	4.0	0.9	1.2

* Ohio

† Ammonia + Nitrite + Nitrate Nitrogen

TABLE D-24. SIGNIFICANCE OF POTENTIAL NONPOINT SOURCES OF WATER POLLUTANTS ASSOCIATED WITH ANIMAL AGRICULTURE

Source Category	Poultry	Dairy	Swine	Beef
Production Facilities	-	0	0	0
Land Used for Manure Disposal	+	+	+	+
Manure Storage Facilities	-	0	-	-
Pasture and Rangeland	*	+	+	+
Silos	*	+	*	+
Milk Houses and Milking Centers	*	+	*	*

+ A potential nonpoint source

0 System dependent

- Not a potential nonpoint source

* Not applicable

SECTION 5

COMPARISON OF THE POLLUTION POTENTIAL OF NONPOINT SOURCES ASSOCIATED WITH ANIMAL AGRICULTURE

The financial and technical resources available to address nonpoint source water quality problems resulting from agricultural activities are not limited. Thus, there is the need to focus attention on those potential sources of pollutants which have the greatest impact on water quality. In allocating program resources, the first step is to determine which agricultural activities - irrigated crop production, nonirrigated crop production, or animal production - are most critical with respect to an identified water quality problem. If, for example, animal agriculture is identified as the most significant contributor of pollutants, the next step is to locate and address those sources which are of the greatest significance.

The purpose of this section is to compare the concentrations of constituents in typical discharges from the various animal agriculture nonpoint source categories. The objective is the identification of those pollutant source categories which should receive priority in animal agriculture best management practice (BMP) implementation programs.

METHODOLOGY

The comparisons which follow were developed using data from several studies. Ranges of values from selected studies rather than averages of all reported values were used for two reasons. First, the intent was to reflect typical situations with respect to management practices. Analysis of available data showed that for certain source categories, average values were not typical values due to the somewhat limited data base.

Second, data from a single study in each source category were compiled to eliminate the effects of possible differences between separate studies. Thus, it was necessary to identify studies for each source category in which all pollutant parameters of interest were measured and reported. Although chemical oxygen demand (COD) data are more commonly reported, five-day biochemical oxygen demand (BOD_5) was used in place of COD for the comparison due to the lack of COD data for silage liquors. This factor limited the number of studies which could be used as data sources, and necessitated the use of two data sources for open confinement areas due to the absence of total phosphorus (TP) data in the study used as the source of BOD_5 values.

Initially, the intent was to compare the nonpoint source potential of open confinement facilities for dairy cattle, beef cattle, and swine in order to characterize the relative significance of such sources as a function of animal species. However, little information exists on the characteristics of runoff from open confinement facilities for dairy cattle and swine. Therefore, this comparison was not possible, and it was necessary to use data from beef cattle feedlot studies as generally indicative of runoff characteristics for all open confinement facilities.

The comparisons were developed using pollutant concentrations, even though there are limitations to this approach. Quantities rather than concentrations of pollutants are discharged and are more indicative of potential water quality impacts. The use of areal pollutant yields, quantity per unit land area per unit time, is inappropriate however, for nonpoint sources such as milk houses, milking centers, manure storage facilities and silos; pollutant discharges in these cases are not the result of land-based activities. In order to include these potential nonpoint sources, the comparisons were based on pollutant concentrations.

SOURCE CATEGORY COMPARISONS

The results of the selected studies are summarized in Table D-25. The comparisons of significance using BOD_5, total nitrogen (TN), and TP concentrations as parameters are presented in Figures D-1, D-2, and D-3. Data for fecal coliform and fecal streptococci concentrations and ratios are summarized in Table D-26.

When BOD_5, TN, and TP concentration ranges are compared, animal agriculture pollutant source categories appear to be divisible into two distinct groups, "concentrated" and "diffuse" nonpoint sources. Those nonpoint sources producing high BOD concentrations, generally greater than 300 mg/ℓ, are often confinement facilities, milk houses, milking centers, silos, and manure stacking facilities. Manure disposal sites and pastures and rangeland produce lower BOD concentrations and form the diffuse nonpoint group. Total nitrogen and total phosphorus concentrations in runoff from manure disposal sites and pastures and rangeland also are substantially less than those associated with the concentrated nonpoint sources (Figures D-2 and D-3). These general groupings also appear applicable to the potential for microbial contamination based on indicator organism concentrations (Table D-6).

Although pollutant concentrations in runoff from diffuse nonpoint sources are substantially lower than concentrated nonpoint sources, total quantities of pollutants discharged from these diffuse sources are likely to be greater. This is due to the greater number and larger area of discharge of these potential diffuse nonpoint sites in comparison to open confinement facilities, milk houses, etc. The immediate water quality impacts of discharges from concentrated nonpoint sources can, however, be greater due to the higher concentrations of pollutants. Even if a dissolved oxygen sag is not observed, the water quality impacts of discharges from concentrated nonpoint sources are more likely to be reflected in increased receiving stream concentrations of BOD_5, TN, TP, etc. than those from the diffuse nonpoint sources.

TABLE D-25. SUMMARY OF DATA USED TO DEVELOP ANIMAL AGRICULTURE NONPOINT SOURCE CATEGORY COMPARISONS(mg/1)

Source Category	Total Solids (TS)	Volatile Solids (VS)	Biochemical Oxygen Demand (BOD_5)	Chemical Oxygen Demand (COD)	Total Nitrogen (TN)	Total Phosphorus (TP)	References
Open Confinement Areas	--	--	2,395-12,750	4,971-30,230	138-2,200	--	Wells *et al.*, 1972
	20,400-77,000	8,700-39,000	--	3,100-41,000	926-21,225	292-361	McCalla *et al.*, 1972
Milk house	2,443-10,610	1,088-6,215	433-4,935	1,474-14,870	58-368	174-269	Martin, 1979
Milking Centers	1,200-6,460	588-4,522	370-2,290	880-6,100	60-560	44-135	Bland, 1980
Silos	--	--	12,550-66,400	--	1,000-5,000	61-613	Ancnymous, 1963
Manure Stacking Facilities	20,000-22,000	10,860-13,002	9,136-9,398	22,000-23,000	1,623-2,339	106-126	Converse *et al.*, 1975
Manure Disposal Sites	--	--	31.2-109.5	120.7-349.2	18.8-50.5	1.2-5.2	McCaskey *et al.*, 1971
Pasture and Rangeland	--	--	6.4-9.8	--	1.2-1.4	0.4-0.6	Robbins *et al.*, 1971
Cropland	--	--	8-11	56-466	2.8-3.2	0.5-1.7	Dornbush *et al.*, 1974

Figure D-1. Comparison of 5-day biochemical oxygen demand concentrations in discharges from in discharges from various animal agriculture nonpoint sources.

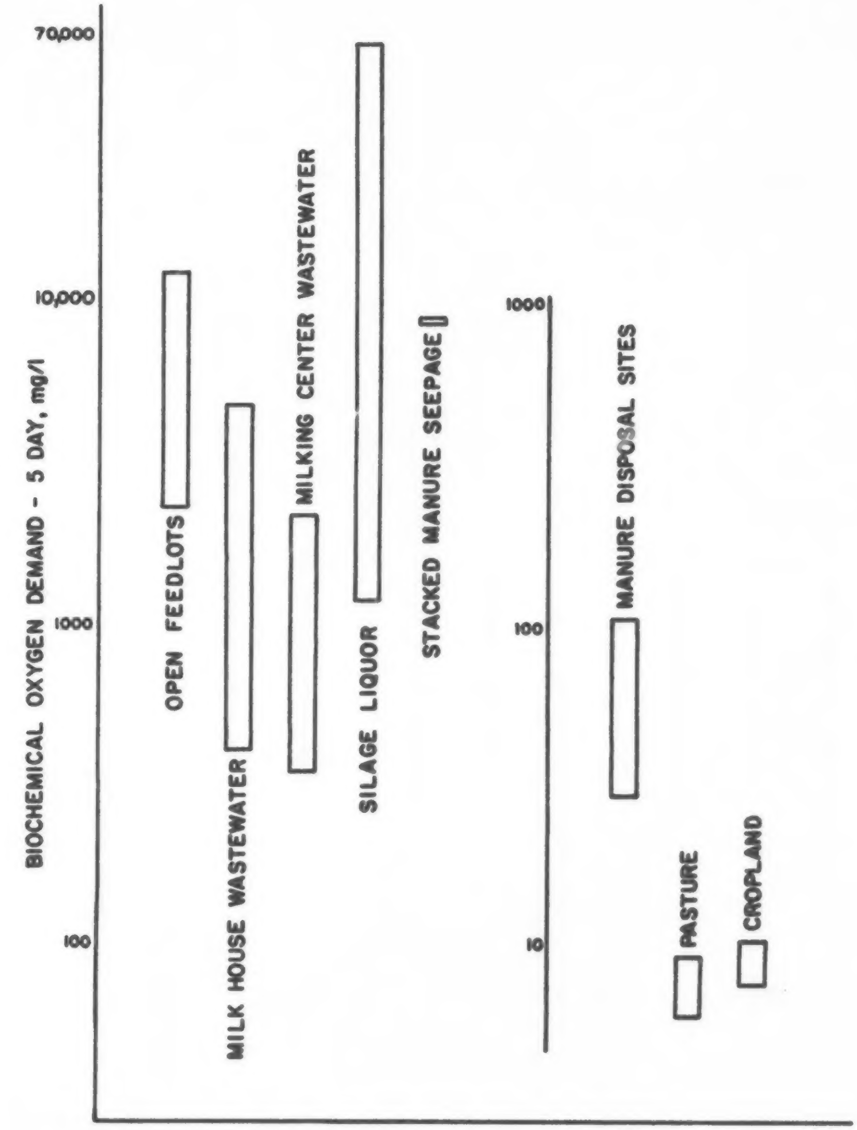

Figure D-2. Comparison of nitrogen concentrations in discharges from various animal agriculture nonpoint sources.

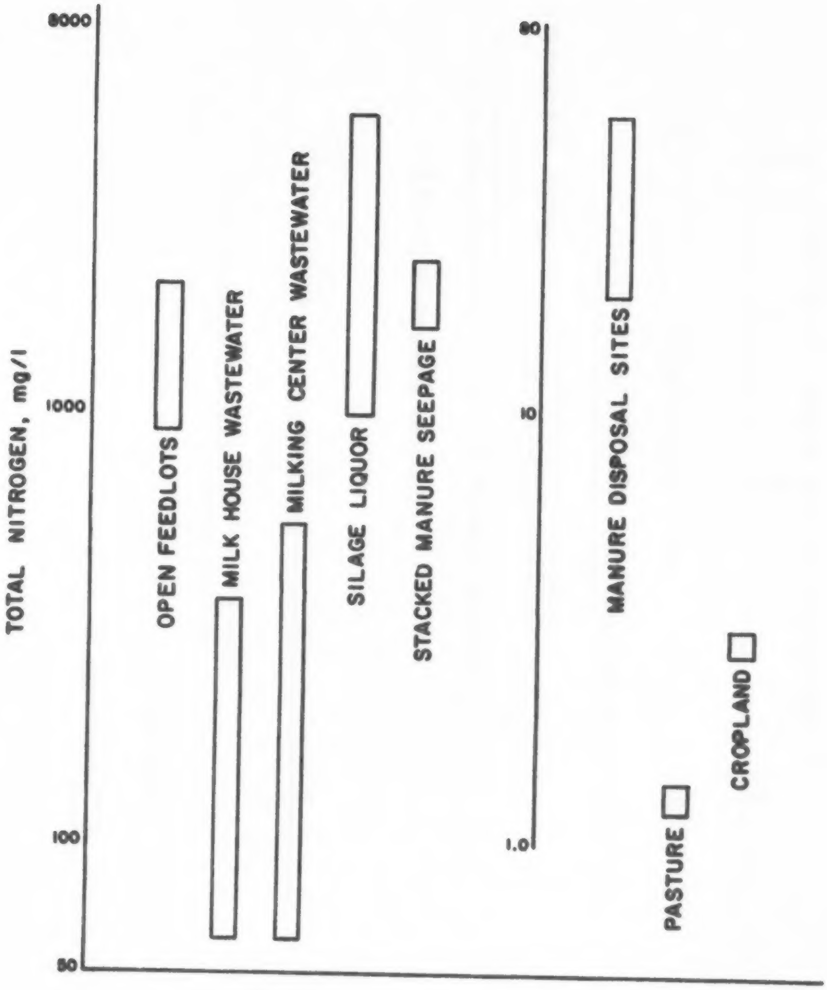

Figure D-3 Comparison of phosphorus concentrations in discharges from various animal agriculture nonpoint sources.

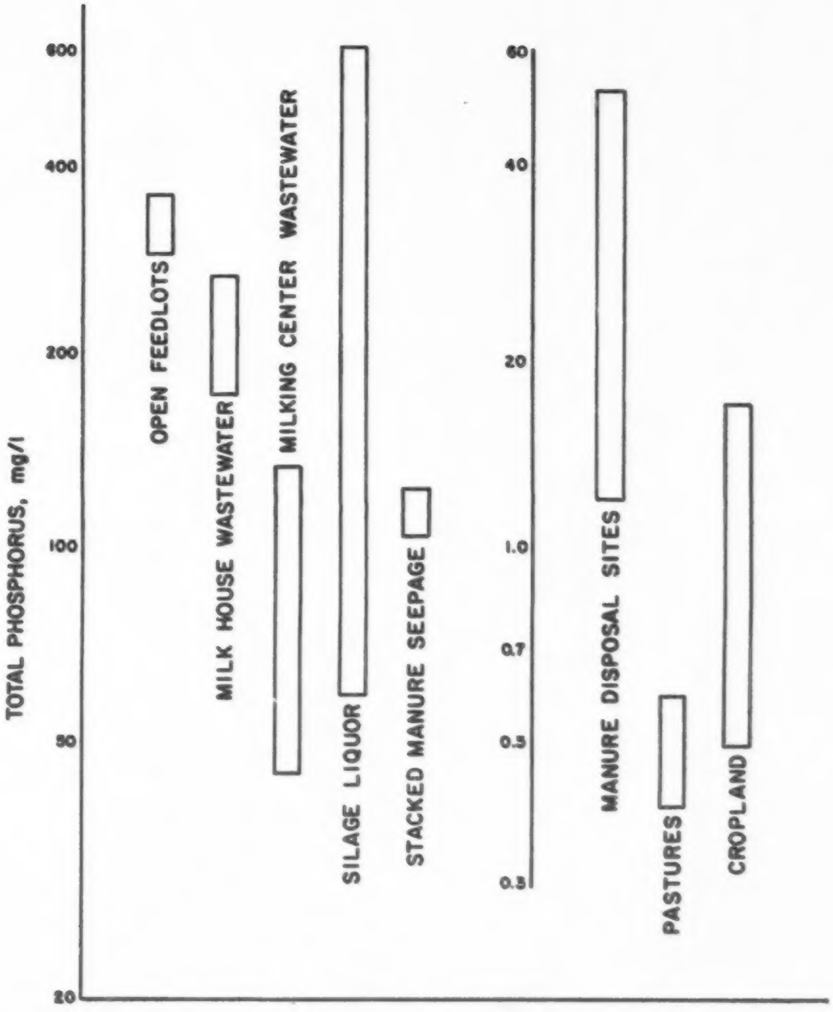

TABLE D-26. COMPARISON OF CONCENTRATIONS OF INDICATOR ORGANISMS, FECAL COLIFORM AND FECAL STREPTOCOCCI, AND FECAL COLIFORM TO FECAL STREPTOCOCCI RATIOS IN DISCHARGES FROM VARIOUS ANIMAL AGRICULTURAL NONPOINT SOURCES

	Range of Values			
	No. per 100 ml.		Ratio	
Source Category	Fecal Coliform	Fecal Streptococci	Coliform/Streptococci	Reference
Milking Center Wastewater	$2.2x10^6$-$2.3x10^7$	$5.9x10^5$-$3.0x10^7$	0.6-3.7	Bland, 1980
Manure Disposal Sites	$1.1x10^3$-$3.8x10^3$	--	--	McCaskey *et al.*, 1971
Pasture	$3.0x10^4$-$3.5x10^5$	--	--	Robbins *et al.*, 1971
Cropland	$1.4x10^3$-$14x10^3$	$3.5x10^4$-$10.7x10^4$	0.04-.131	Dornbush *et al.*, 1974

While water quality data should be useful in identifying pollutant discharges from concentrated nonpoint sources, distinguishing between water quality impacts of runoff discharges from manure disposal sites, pastures and rangeland, and cropland using water quality data will be more difficult. This is particularly true for pastures and rangeland versus cropland. As shown in Figures D-1, D-2, and D-3, concentrations of BOD_5, TN, and TP in pasture and rangeland runoff and cropland runoff will be similar. Sediment losses from pasture and range areas should, however, be lower than those from cropland, particularly in situations involving row crops.

SUMMARY

These comparisons suggest that the concentrated animal agriculture nonpoint source categories should receive priority in the allocation of available financial and technical resources for BMP implementation with the next priority given to land used for manure disposal. As possible sources of nonpoint pollutant discharge, pastures and rangeland could have still lower priority until water quality problems associated with land used for irrigated and nonirragated crop production are effectively addressed.

The objective in developing these comparisons was to establish which source caregories were likely to have the greatest water quality impact and what the priorities might be for allocating resources for addressing nonpoint water quality problems. Care should be taken in applying these generalizations to specific situations. A number of site specific factors such as location relative to surface waters of concern, management practices employed, etc. must be considered before the relationship of any potential pollutant source to an identified water quality problem and the need to implement BMPs can be determined.

SECTION 6

ANIMAL AGRICULTURE
POLLUTION CONTROL ALTERNATIVES

Once it has been determined that an observed water quality problem is related to animal agriculture, and the physical source or sources of the responsible pollutant discharges have been identified, it is then possible to select a practice or combination of practices that will effectively address the problem. Due to variables such as established water quality goals, availability of capital, management capabilities, physical constraints, etc., the selection of effective practices is a site specific process. **There is no pollution control practice or combination of practices that can be designated as most suitable for each of the animal agriculture nonpoint pollutant source categories previously identified.** The purpose of this section is to identify and discuss available pollution control alternatives for each pollutant source category.

OPEN CONFINEMENT FACILITIES

There are several available options for addressing nonpoint water quality problems associated with open confinement facilities. Runoff collection systems have been used extensively and effectively for commercial feedlots to control polluted runoff. The level of pollution control provided by runoff collection systems is dependent on the storm frequency used for design of the storage pond. If, for example, the design objective is to provide total containment up to a 25-year, 24-hour storm event, pollutant discharges and resultant water quality impacts will be minimal. This level of runoff control has been designated as best available technology economically achievable for feedlots which are point sources or pollutant discharges.

Although runoff collection systems can be highly effective in reducing pollutant discharges, the land area for ponds and associated collection channels and settling basins can be significant and may not be available when confinement facilities are located immediately adjacent to streams or major drainage channels. In addition to the possible loss of productive land, runoff collection systems impose a continuing labor requirement for maintenance and dewatering. Normally, dewatering is accomplished by surface or spray irrigation of accumulated runoff on adjacent pasture or cropland. Periodic removal of settled solids from settling basins or collection ponds also is necessary. Detailed information concerning runoff collection systems for open confinement facilities, including design parameters, is available from sources such as Shuyler et al. (1973), Miner and Smith (1975), and Midwest Plan Service (1975).

Commonly, a substantial fraction of the surface runoff from an open confinement facility originates from sources outside the facility such as upland areas and from roofs of adjacent buildings. Thus, practices such as constructing diversion terraces to intercept surface runoff from upland areas and installing gutters and leaders to collect and divert roof runoff can significantly reduce the volume of contaminated runoff and the quantities of pollutants that must be controlled or that are discharged. Practices to reduce runoff volume should be used in combination with runoff collection systems to reduce storage capacity and dewatering requirements.

Diverting upland runoff and installing gutters may, in many instances, reduce pollutant discharges from open confinement facilities to levels that will permit attainment or maintenance of desired water quality goals. When this does not occur, additional reductions in pollutant discharges, particularly particulates, may be obtained by combining practices to control runoff volume with grassed outlets or vegetated buffer strips.

In situations where runoff reduction is not sufficient to decrease pollutant discharges to a level compatible with established water quality goals, and physical constraints preclude construction of a runoff collection system, conversion of open confinement facilities into totally enclosed production units may be an appropriate pollution control alternative. This approach may be at least partially justified in certain climatic regions by improvements in feed efficiency, reduced labor requirements, and improved working conditions. Another option is to relocate an open confinement facility to an area hydrologically remote from streams and major drainage channels, assuming that a suitable site is available.

LAND USED FOR MANURE DISPOSAL

Land used for manure disposal is a potential nonpoint pollutant source common to all confined animal production activities. Water quality problems related to manure disposal sites can be most effectively addressed by management practices that reduce the probability of pollutant transport during runoff events, such as:

1) Elimination of excessive application rates,
2) Timing of manure applications,
3) Soil incorporation of manure, and
4) Other practices.

Application Rate

Application rates of manures to pasture and cropland should be based on plant nutrient content and agronomic need using soil test results and estimates of crop residue nutrient content and uncontrollable nutrient losses. Both nitrogen and phosphorus requirements should be considered in determining appropriate application rates. Applying manures to satisfy crop nitrogen requirements may result in overapplication of phosphorus. A detailed methodology for determining manurial application rates that will minimize pollutant losses has been outlined by Gilbertson et al. (1979).

Disposal of manure on unproductive land should be avoided particularly due to underutilization of plant nutrients which remain available for transport via surface runoff. Where daily manure spreading is practiced and cropping patterns preclude the use of productive land for manure disposal during the growing season, plant nutrient conservation may justify manure storage as a production as well as a pollution control practice. When all animal feedstuffs are purchased, use of productive land on adjacent farms appears to be the only feasible pollution control alternative available.

Timing of Manure Disposal

Ideally, applications of manures as well as manufactured fertilizers should coincide with crop needs to maximize plant nutrient utilization and reduce the potential for runoff losses. Thus, utilizing manures as side-dressing for row crops and top-dressing for hay crops and pastures to the greatest extent possible can be highly desirable with respect to both nutrient utilization and pollution control. Although top-dressing of hay crops and pastures with manures is common, equipment to apply manures as side-dressing for row crops is not, at present, commercially available. When it is necessary to apply manure before planting, application should be scheduled to coincide as closely as possible with the commencement of tillage operations recognizing possible labor and equipment conflicts.

Spreading of manure on frozen and/or snow-covered soil is generally recognized as a practice that should be avoided particularly due to pollutant losses associated with critical runoff events. Thus, manure storage is commonly cited as a pollution control practice because winter manure-spreading can be avoided. Disposal of stored manure particularly in the spring can, however, create labor and equipment conflicts and produces intense periods of manure-spreading which can negate possible water quality benefits if a significant runoff event occurs.

The timing of manure applications should be based on local weather patterns as delineated by temperature and precipitation records. This will permit identification of time periods in which the probability of runoff events, particularly critical events such as rapid snowmelt, is high. Months generally suitable for manure disposal for various climatic regions are outlined in Table D-27.

The establishment of field priorities for manure disposal (Walter et al., 1978) is a possible alternative to construction of storage facilities to reduce water quality impacts related to winter manure spreading. The basis of this approach is the ranking of available manure disposal sites with respect to pollutant discharge potential using criteria such as location relative to streams and major drainage channels, slope, nature of vegetative cover, etc. Then a manure-spreading schedule can be developed to avoid critical areas during periods of high rainfall or snowmelt runoff event probability.

TABLE D-27. MONTHS GENERALLY SUITABLE FOR MANURE DISPOSAL FOR VARIOUS CLIMATIC REGIONS (Gilbertson *et al*., 1979)

	-------------------- Climatic Regions of the United States -----------------							
	Cold		Cool		Warm		Hot	
Manure Form	Humid	Arid	Humid	Arid	Humid	Arid	Humid	Arid
Solid	May June Aug. Sept.	May June Sept.	April May Oct. Nov.	April May Oct. Nov.	March April Aug. Sept. Oct.	Year-round	Year-round	Year-round
Slurry	May June July Aug. Sept.	April May June July Aug. Sept. Oct.	March through Dec.	April May Aug. Sept. Oct. Nov.	Year-round	Year-round	Year-round	Year-round
Liquid (runoff)	May June July Aug. Sept.	May June Sept.	March through Dec.	March through Dec.	Year-round	Year-round	Year-round	Year-round

Soil Incorporation of Surface Applied Manure

Runoff losses of pollutants from manure disposal sites also can be reduced by subsurface application (injection) or immediate incorporation by plowing or discing. In addition to water quality benefits, these practices can reduce ammonia volatilization losses of nitrogen, which can be significant for surface applied manures. In experiments conducted in April and August, a 25 percent loss of ammonia nitrogen from surface applied dairy cattle manure in the first 24 hours following application has been observed (Lauer, 1975). In 5 days, the average loss exceeds 40 percent. Thus, immediate soil incorporation of manures also may have significant productive benefits by reducing nitrogen fertilizer requirements and associated costs.

Incorporation of manures into the soil by plowing or discing is not, however, applicable in situations where no-till or conservation tillage practices are employed for erosion control and on land used for hay crops or pasture. When fall applications of manure are incorporated into the soil by plowing or discing, the potential for increased soil erosion due to the absence of vegetative cover during winter months may negate other water quality benefits.

Other Practices

Many of the management practices that have been identified for control of water pollution from cropland, particularly practices that control runoff volume and vegetative practices such as field borders and buffer strips, also may be effective in reducing pollutant discharges from manure disposal sites. These practices have been described in Section 3, Nonpoint Source Control Practices, of this report and by Stewart et al. (1975).

MANURE STACKING FACILITIES

Alternatives available to control pollutant discharges from manure stacking facilities are limited. Although runoff can be eliminated by enclosing open stacking sites, seepage losses will still occur. Thus, enclosing open stacking facilities will not eliminate the need for retention ponds to provide for controlled disposal of liquids to pastures or cropland. In addition, seepage losses during summer months may be greater for enclosed as compared to open manure stacking facilities due to reduced evaporation losses (Tenpas et al., 1972). Therefore, the trade-off in costs for enclosing open stacking facilities and for additional retention pond volume for runoff storage should be carefully examined.

PASTURE AND RANGELAND

Nonpoint water quality problems related to confined animal production activities are most effectively addressed by employing fundamentally sound pasture and management practices. Practices such as overgrazing should be avoided. Stocking rates and grazing systems that maximize sustained forage yield will minimize manure accumulations and reduce surface runoff by maintaining vegetative cover and minimizing soil compaction. Guidance in identifying appropriate stocking rates for various animal species, types of vegetation, grazing systems, and geographic regions is available from a number of sources such as Ensminger (1970).

Winter pastures and areas of animal congregation, such as shaded and protected areas, and around watering troughs, salt sources, etc. should be relocated to areas hydrologically remote from streams and major drainage channels whenever possible to minimize water quality impacts associated with resultant manure accumulations. Manure accumulations around watering throughs and salt sources can be reduced by periodic relocation. At sites where significant manure accumulations are present, tillage, particularly discing, can be used to break up, distribute, and incorporate manure into the soil. Accumulations of manure also can be removed periodically and applied to cropland or more evenly on pastures.

Although animal access to surface waters should be minimized, the necessity of total stream fencing as a pollution control practice is unclear. It may be possible to achieve desired water quality goals by restricting animal access to streambank areas where destabilization can occur and by reducing the need for animal congregation in streams to obtain relief from heat and insects. The latter can be encouraged by providing shade and using insecticides. These alternatives should receive careful consideration, particularly for range areas, when it is necessary to develop alternative sources of drinking water as a consequence of stream fencing.

SILAGE LIQUORS

Studies examining the impact of silage liquor losses on feedstuff value have shown that moisture content control can effectively reduce both the volume and duration of silage liquor seepage. At moisture contents of 70 percent or less, silage liquor seepage is essentially nil (Wittwer et al., 1958 and Moore, 1962). Due to losses of feedstuff value via seepage, recommended moisture content values for crops to be ensiled range from 60 to 70 percent (Moore, 1962 and Ensminger and Olentine, 1978). Thus, water quality problems associated with silage liquors can be simply and effectively addressed by employing sound ensiling practices.

It should, however, be recognized that precise control of silage crop moisture content is not always possible. Thus, provisions for silage liquor collection and disposal may be warranted. Most silos are constructed with drainage systems which will facilitate collection of silage liquors. When seepage occurs through silo walls, diking to collect silage liquors and divert surface runoff will be necessary. Due to the plant nutrient content of silage liquors (Table D-12), productive land should be used for disposal. Where available, liquid manure storage facilitates and collection ponds for manure stacking facilities can be used to store collected silage liquor.

MILK HOUSE AND MILKING CENTER WASTEWATERS

Water quality problems related to milk house and milking center wastewaters differ from typical nonpoint water quality problems in that pollutant discharges can be independent of runoff events. Water quality problems associated with these waste streams are best addressed by collection, storage, and/or treatment prior to disposal. One alternative is combined storage and disposal of these wastewaters with liquid manure. Although this approach has the advantage of simplicity, manure disposal requirements are increased and manure storage capacity is reduced due to increased volume.

A second alternative is to use facultative lagoons or ponds for treatment and storage. Lagoons and ponds have been demonstrated to be an effective and practical approach for milking center wastewater management and also appear applicable for milk house wastewaters. When designed and managed properly, these structures provide nuisance-free storage as well as waste stabilization. Labor and management requirements are minimal, and a source of water for fire protection is available possibly reducing fire insurance costs. Design parameters for milking center wastewater lagoons have been established and are available (U.S. Department of Agriculture, 1977).

Other options for management of milk house and milking center wastewaters include direct controlled land application, use of vegetative filters, and controlled stream discharge. In climatic regions where freezing problems will not be encountered, controlled land application of these wastewaters by either spray or surface irrigation on a daily basis is another possibility. If application rates are based on soil infiltration capacity, runoff during irrigation and associated pollutant transport can be avoided.

For situations where total abatement of pollutant discharges is not necessary to attain desired water quality goals, or implementation of the previously discussed control practices is not possible, use of vegetative filters to reduce quantities of pollutants discharged should be considered. The effectiveness of vegetative filters, particularly with respect to removal of organic solids, nitrogen, phosphorus, and microorganisms, has been demonstrated in a number of studies involving municipal and other agriculturally related wastewaters. Results of these studies suggest that this pollution control approach also should be applicable to milk house and milking center wastewaters. Data to characterize performance and to establish design and operating parameters is, however, presently unavailable.

A final alternative for addressing water quality impacts related to milk house and milking center wastewaters is controlled stream discharge. Although quantities of pollutants discharged will not be reduced, the impacts of slug loads associated with milking events can be eliminated by uniform discharge throughout the day. This approach is recommended only when all other alternatives are not feasible.

SUMMARY

The selection of pollution control practices to address water quality problems related to animal production activities is a relatively simple task due to the limited number of available options (Table D-28). In considering available options, effectiveness with respect to desired water quality goals, costs, particularly private capital costs, and labor and management requirements should receive careful consideration.

TABLE D-28. SUMMARY OF SUGGESTED PRACTICES TO ADDRESS WATER QUALITY PROBLEMS ASSOCIATED WITH ANIMAL PRODUCTION ACTIVITIES

Open Confinement Facilities	Runoff collection, runoff diversion, vegetative practices - grassed outlets and buffer strips, enclosing open facilities, relocation.
Land Used For Manure Disposal	Use of application rates based on agronomic need; timing of manure application - side-dressing and top-dressing, avoidances of time periods with high runoff probability, storage, and establishment of field priorities; injection or immediate soil incorporation; and vegetative practices - field borders and buffer strips.
Manure Stacking Facilities	Retention ponds
Pasture and Rangeland	Use of recommended stocking rates; discourage animal congregation in critical areas including streams; breakup, distribution, and incorporation or removal of manure accumulations; and restriction of animal access to highly erodible areas.
Silage Liquors	Use of recommended ensiling practices and collection of seepage from silos.
Milk House and Milking Center Wastewaters	Combined storage and disposal with liquid manures, lagoons and ponds, controlled land application, vegetative filters, and controlled stream discharge.

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APPENDIX E

WATER QUALITY IMPACT AND CONTROL ALTERNATIVES ASSOCIATED WITH THE USE OF INSECTICIDES

C. A. Shoemaker and M. D. Harris

SECTION 1

INTRODUCTION

There are a wide range of practices which can be used to reduce the movement of pesticides into the environment. Unfortunately, because of the diversity of cropping systems and the large number of chemically dissimilar pesticides in use, it is difficult to make general statements about which of these practices are feasible and most effective for a given situation. **The purpose of this report is to describe some of the practices which are available and to discuss the factors which may influence their success in reducing pesticide transport. The bulk of the report consists of a tabulation of the information available on chemical characteristics, toxicity, transport and effectiveness of control procedures for a large number of commonly used insecticides.**

Management practices for reducing pesticide transport include the following:

1. Procedures which reduce the amount of pesticide applied. Example: integrated pest management.
2. Changes in application procedures to reduce the amount of pesticide transported away from target areas. Example: replacing aerial applications by ground applications which have made lower drift losses.
3. Improved control of disposal of surplus pesticide and pesticide containers. Example: requiring a substantial deposit on pesticide containers.
4. Changes in timing of application to reduce the amount of pesticide transported. Example: avoiding applications which are followed shortly by rain.
5. Implementation of soil and water conservation practices to reduce the transport of water-born pesticides. Example: use of strip-cropping.

SECTION 2

CONCLUSIONS

There are a large number of practices which can be developed to reduce the transport of pesticides into non-target areas. The effectiveness and costs of each of these practices will vary among crops, pests and geographical regions. In deciding which practices to implement, we should consider the impact of a practice on all pathways of pesticide transport, including transport by air, water, improper disposal or accidental spills. Practices which reduce the amount of pesticide used are the only methods which reduce transport via all pathways simultaneously. For this reason, a **high priority should be given to the implementation of practices like pest management, which reduce the amount of pesticide applied. If a comprehensive integrated pest management program is not available for a particular pest and crop, sometimes pesticide use can be reduced by implementation of relatively simple programs involving the use of scouting or cultural control methods like crop rotation.** Other important methods which are likely to be available in the short term are replacement of aerial applications of pesticides with ground applications, improvements in timing of pesticide applications, additional controls on disposal, soil and water conservation practices, and substitution of the current pesticide with another which is less mobile. In the longer term, we would hope to see the development of more selective chemical and microbial pesticides, additional resistant plant varieties and comprehensive integrated pest management programs for an even wider range of crops.

SECTION 3

PATHWAYS OF PESTICIDE TRANSPORT

Pesticides move into the environment by several pathways. **The major pathway for most pesticides appears to be air-borne transport resulting from drift during application or volatilization during or after application.** Gerakis and Sficas (1974) have estimated that about one-half of the pesticide applied to field crops enters the atmosphere through evaporation from soil and plant surfaces. Drift is usually defined as the percentage of pesticide applied which does not reach the targeted field. Drift losses can be quite substantial, especially with aerial applications. For example Ware et al (1970) found that 45% of the methoxychlor applied did not reach the foliage or ground in their five acre target plot. In this experiment the applicator plane was only 5-6 feet above the alfalfa crop and the wind speed was only 3.6 mph. Garston et al (1968) reported that 30 minutes after Amitrole spray was applied aerially to 100 acres in a watershed it appeared in stream waters at concentrations of 155 ppb. Drift losses are usually lower for ground applications, especially for granular formulations.

Pesticides can also be transported into the environment by water. Pesticides carried in runoff may either be dissolved in solution or sorbed onto soil particles. The fraction of pesticide sorbed onto soil particles will influence the amount of material which is transported and the effectiveness of procedures to control this transport.

The amount of pesticide which is transported by surface runoff is usually smaller than air-borne losses. In an extensive review of the literature on pesticide losses in runoff, Wauchope (1978) estimates that the highest average losses will be about five percent of the applied material for wettable powder herbicides whose application is followed by rains. Wauchope estimated losses from organochlorine insecticides currently in use to be about one percent or less of the applied material. He estimated that losses of most other pesticides would average .5 percent or less of the material applied.

Leaching losses of strongly or moderately absorbed pesticides tend to be quite small. However, highly soluble pesticides like Aldicarb can pose serious problems to groundwater quality when applied to well drained or sandy soils. Recently about a fourth of over 500 wells tested in Suffolk County, New York had concentrations of Aldicarb in excess of 7 ppb, a standard suggested by a National Academy of Sciences report (1977) and by the New York State Department of Environmental Conservation (Severo, 1980).

Improper disposal can also be significant in the transport of pesticides to non-target areas. As a result, it is recommended that containers be rinsed and punctured before disposal. In a study at Southern Illinois University, 600 five gallon used pesticide containers were sampled at one farm disposal site. It was found that less than forty percent of the containers had been rinsed. Several cans had between one quart and 4.25 gallons of undiluted pesticide in the discarded container. Another study at Oregon State University has shown that on the average, nearly six ounces of pesticide is left in unrinsed five-gallon containers (Luckman et al, 1978).

Each of the management practices for controlling pesticide transport affects the movement of pesticide in different ways. In most cases, a practice obstructs movement along a single pathway. For example, soil and water conservation practices may reduce the amount of pesticide carried in runoff, but they do not decrease drift losses. **The only practices which diminish the movement of pesticides along all pathways are those practices which reduce the amounts of pesticide used. For this reason such practices should be given first consideration in areas where they are feasible and effective.**

SECTION 4

REDUCTION IN PESTICIDE USAGE THROUGH INCREASED EFFICIENCY OF PEST CONTROL

New developments in pest control technology have resulted in dramatic decreases in the use of pesticides for some serious insect pests. Much of this reduction in pesticide use has been the result of the utilization of non-chemical methods of pest control in conjunction with improvements in timing of pesticide applications.

SCOUTING

Pest management is a term which is used to describe the effective co-ordination of a variety of pest control techniques to contain a pest population. Several principles are involved in the development of pest management programs. Control procedures should be implemented only when they are economically justified. This principle has resulted in **the concept of an "economic threshold", which is the minimum pest density that justifies a pesticide application.** Below this density, no pesticide should be applied. This policy **represents a marked departure from earlier programs in which pesticide was applied on a fixed schedule regardless of pest density.**

In order to implement an "economic threshold" policy for timing pesticide applications, it is necessary to sample the pest population to determine its density. Such a sampling program is called "scouting". Based on a survey of cotton entomologists in 1972-74 the reduction in insecticide use for control of cotton insects has been estimated to be around twenty-three percent as a result of scouting (Pimentel et al., 1979).

RESISTANT PLANT VARIETIES

Nonchemical means of suppressing pest populations include cultural and biological control methods as well as the use of resistant plant varieties. **Resistant varieties have been widely used for many years and will continue to be a very important means of pest control in the future.** Unfortunately in some situations, high yielding resistant plant varieties are not available. It may take years or even decades to develop a commercially available resistant variety. The investment in time has been well rewarded. For example, wheat varieties resistant to Hessian fly have been available for years and have been tremendously important in reducing the need for insecticides in wheat production. Cotton varieties such as frego bract cotton with resistance to boll weevils are currently being developed for commercial use in the South.

CULTURAL METHODS OF PEST CONTROL

Cultural pest control methods involve the physical alteration of the crop ecosystem. Common **examples of cultural control procedures are changes in planting dates or harvest dates.** Such changes affect the synchrony of the pest with the host crop and can thereby reduce the amount of crop damage. For example, in New York a computerized pest management system using regional scouting information and weather data advises farmers when densities of alfalfa weevils are sufficiently high to justify an early cutting. Changes in planting or harvest dates are often done in conjunction with the use of special plant varieties or alterations in irrigation schedules so that the crop matures in a shorter period of time. This procedure has been widely used in cotton production in Texas and has significantly reduced insecticide use.

Another very important cultural means of controlling pests is crop rotation. Many pests, like the southern corn rootworm, require continuous presence of the host crop to complete its life cycle. By rotating corn with a nonhost crop like soybeans, corn rootworm can be suppressed to non-damaging levels. Although crop rotation was widely used before the development of modern pesticides, many farmers are reluctant to use the crop rotations because they are sometimes less profitable than continuous growing of a high-value crop.

BIOLOGICAL CONTROL

Biological control refers to the use of biological organisms to suppress pest populations. **Insect parasites and predators, for example, can significantly decrease the size of pest populations, sometimes to the point where pesticide applications are no longer necessary.** One of the most successful examples of this type of control is the establishment of two insect parasite populations which have successfully controlled the olive parlatoria scale. This insect was the most serious pest of olives in California before the parasites were introduced (Huffaker and Kennett, 1966). These parasites have been so effective that currently pesticide control is almost never used for control of olive paralatoria scale. One of the greatest advantages of this type of biological control is that once it is established, it continues at no cost to the farmer.

Another form of biological control is the enhancement of the effectiveness of natural enemies of the pest which are already present in the crop field. This enhancement usually involves measures which increase survivorship of the natural enemies. A major cause for mortality of insect parasites and predators is the presence of pesticide applied to suppress pest populations. Reduction or elimination of pesticide applications during periods when natural enemies are susceptible can greatly enhance the effectiveness of natural control.

Another form of biological control is the use of pathogens which attack pest populations. Commercial mixtures of such pathogens used for short-term pest control are called microbial pesticides. The most commonly used microbial pesticide is Bacillus thuringiensis which is applied for the control of lepidopterous insects. The advantage of a microbial pesticide is that is usually only attacks a specific range of lower organsims and is not expected to harm natural enemies or to persist in the environment in the absence of host species. Microbial pesticides have several disadvantages. The first is that they are sometimes not as toxic to the target species nor as economical as competing chemical pesticides. Secondly, microbial pesticides must be extensively tested before registration to prove that the organisms or its mutants will not be harmful to man or nature. Because of the expense of such testing and because of the small market for materials which are toxic to only a narrow range of pests, relatively few micorbial pesticides are available.

OTHER PEST CONTROL METHODS

Attractants are also used to monitor pest populations and as a direct control method. For example, Mediterranean fruit fly populations have been suppressed by the distribution of a protein hydrolysate bait containing malathion. The attractiveness of the bait provides pest control with much less insecticide than would have otherwise been necessary. Attractants in traps can also be useful in estimating pest population densities and thereby ascertaining the best time to apply pesticides in order to maximize effectiveness. In citrus orchards, traps containing female California red scale may catch thousands of males. From the trap data, the damage potential from the pest and the need for a pesticide treatment can be estimated.

The traps containing live females are effective in attracting males from a long distance because the female releases a chemical called a sex pheromone which males can detect even in extremely low concentrations. For some insects the chemical structure of the pheromone has been discovered. Commercially synthesized pheromones are also used in traps. As a direct control measure, pheromones have been applied to crop fields in order to disrupt insect mating and thereby reduce the size of subsequent generations of the pest.

Crops themselves are sometimes used as traps. In cotton, for example, a trap crop for cotton boll weevil is developed by planting about 5% of the cotton two or three weeks before the rest of the crop is planted. The emerging boll weevils are attracted to the early cotton which is then heavily sprayed with insecticide. This reduces the amount of insecticide necessary to control the pest over the entire cotton acreage. An economic analysis of the costs and benefits associated with early trap crops in cotton indicate that trap crops reduce production costs (including pesticide costs) by about $6.80/acre. (Pimentel et al., 1979).

The environmental advantages of pheromones and microbial pesticides are associated with the relatively narrow spectrum of organisms which are susceptible to their harmful effects. It is also possible to develop chemical pesticides which are toxic to only a few closely related species. If their selectivity makes them less toxic to insect parasite and predators, selective pesticides are very useful in programs to enhance the effectiveness of natural enemies for a pest population. However, because of the multi-million dollar cost of developing and testing a pesticide, the pesticide, industry is reluctant to make such an investment in a product which will have a small market. As a result, selective pesticides are not as available as one might wish.

There are many other practices being developed for improving the effectiveness of pest control programs. Among these other practices are the application of juvenile hormones and the release of sterile males. In the later procedure, males which have been sterilized by chemicals or radiation are released into the natural population to mate with mature females. The method is most effective if the sterile males greatly outnumber the fertile males and if the female mates only once.

INTEGRATED PEST MANAGEMENT

Since a range of pest control methods is available, plant protection research in recent years has put an increasing emphasis on a more effective means of integrating these techniques. In most cases the development of such programs has reduced the need for pesticides. For example, based on a survey of cotton entomologists in 1972-1974, Pimentel et al., (1979) computed that implementation of the most economical integrated pest management practice in each cotton growing region would reduce insecticide use by an average of 40%.

Effective integrated pest management usually involves a detailed biological study of the population dynamics of the pest, its host crop and its natural enemies. From such studies, an understanding can be gained of the impact of management practices on the interactions among populations. Armbrust et al., (1980) illustrate the approach to such a comprehensive analysis of alfalfa weevil control. Because of the complexity of the crop ecosystem, techniques of systems analysis have been found to be increasingly useful in developing integrated pest management programs (Shoemaker, 1979, 1980; Norton and Holling, 1979; Shoemaker et al., 1978).

An excellent example of an integrated pest management program has been developed in Texas for control of cotton pests. The program utilizes scouting, a short season cotton variety, and protection of natural enemy populations through use of a selective insecticide. The insecticide Azinphosmethyl is effective in controlling boll weevil, but in not harmful to natural biological control agents. Pesticide applications are made only when field scouting indicates they are necessary. The amount of pesticide used is subsequently less than in conventional pest control programs. Because of the short-season cotton variety, these few pesticide applications were sufficient to control the boll weevil before it caused significant crop damage. No pesticide is used against the other major insect pests, the *Heliothis* species. When they are not threatened by the use of wide spectrum insecticides, the natural enemies of the *Heliothis* are more effective that any of the insecticides currently registered in cotton (Phillips et al., 1980).

The economic and environmental benefits of this program are substantial. In the pilot program with normally spaced short season cotton in Frio County, Texas, production required 80% less fertilizer, 50% less water and 75% less insecticide. The net profit of the integrated pest management program was more than double that of the typical producer (Phillips et al., 1980). Hence, it is possible through improved technology to simultaneously decrease pesticide use and to improve farmer income.

SECTION 5

CHANGES IN APPLICATION PROCEDURES TO REDUCE PESTICIDE TRANSPORT

REDUCTION IN DRIFT LOSSES: IMPACT OF GROUND APPLICATION, DROPLET SIZE, AND PESTICIDE FORMULATION.

Ware et al., (1970, 1975) have shown that much more drift occurs during aerial application of pesticides than with the use of ground sprayers. For example, Adair et al., (1971) found that following an aerial application of methyl parathion, less than 50% of the applied pesticides was recovered on the ground in an area which included the target field plus the area 800 meters downwind from the field. In an extensive review of drift losses by von Rumker et al. (1975), drift losses from ground applications are estimated to be between 0% and 40% of the pesticide applied. Byass and Lake (1977) have shown that even small drift losses can be hazardous. They observed that drift losses of less than 1% of the applied picloram caused significant damage to sensitive plant species located downwind.

Although ground applications are more effective at reducing drift losses, aerial applications are often preferred for a variety of reasons. First they may be somewhat less expensive. In Texas for example, ground application costs between $3.25 and 3.50/acre. Aerial application costs are between $2.25 and $2.75 per acre, depending on the volume of material applied (LeClair, 1977 personal communication). Another advantage of an aerial application is that planes can cover a large area much more quickly than is possible with ground equipment. In some areas, the use of ground application equipment may be limited by wet fields or irrigation pipes which obstruct the movement of ground equipment.

Besides being more desirable from an environmental point of view, ground applications have some advantages over aerial applications. The most obvious advantage is that without such substantial drift losses, more of the pesticide remains in the target area where it is more effective in killing target pests. Some entomologists also argue that because the nozzle is closer to the plant, a ground application results in a more thorough coverage of the crop, and hence its pest control effectiveness is enhanced.

Droplet size is extremely important to drift losses. Droplets ranging from 10 to 50 um in diameter are likely to drift up to several kilometers whereas droplets greater than 100 um in diameter rarely drift except in windy conditions (Gerakis and Sficas, 1974). This is one of the reasons why drift is a less serious problem for herbicides which are applied with larger

droplets than for insecticides. Brazzel et al., (1968) have suggested that more progress in the control of drift could be made by the control of the droplet spectrum than by any other means.

The formulation of pesticide also has a large impact on drift losses. For example, in the case of DDT, it was found that dust applications placed fourteen times more material downwind than was found with spray applications (Gerakis and Sficas, 1974). As a result, dust has been largely replaced by spray and granular formulations. Drift is generally lower with granular formulations than with spray applications.

REDUCTION IN VOLATILIZATION LOSSES: SOIL INCORPORATION AND CHOICE OF PESTICIDE

Volatilization is a major factor in the transport of many pesticides. The rate at which this volatilization occurs depends upon environmental factors such as temperature, air flow rate, type of cover crop, soil composition and penetration of pesticide into the plant tissue (Harns and Lichtenstein, 1961; Farmer *et al*., 1973; Lichtenstein *et al*., 1970; Spencer and Cliath, 1977; Kearney *et al*., 1964; Swoboda *et al*., 1971). The rate of volatilization also depends upon characteristics of the pesticide itself, especially its vapor pressure, but also its water solubility and the strength of its absorbtion to soil particles. **Since the volatilization rate depends upon the type of pesticide, one obvious way to reduce pesticide volatilization is to replace a pesticide with a less volatile alternative pesticide.**

Another management practice which can be used to reduce volatilization **is incorporation of a pesticide into the soil during application.** The rate of volatilization of pesticides buried in the soil is much slower than for pesticides on the surface. For pesticides mixed into the soil, the volatilization losses depend upon the rate of pesticide desorption from soil, the rate of diffusion to the soil surface, and the mass flow of water to the soil surface (Spencer and Cliath, 1973; Farmer *et al*., 1973). Farmer and Letez (1974) have further discussed the effects of soil incorporation on volatility and have developed several models for the prediction of volatilization losses.

SECTION 6

REDUCING TRANSPORT OF PESTICIDES BY RUNOFF: SOIL AND WATER CONSERVATION PRACTICES AND NON-PERSISTENT PESTICIDES

Pesticides can be transported from crop fields either dissolved in runoff water or sorbed onto soil particles suspended in runoff water. The partitioning of the pesticide between the dissolved and sorbed state varies considerably among pesticides. **Most pesticides used in agriculture are transported primarily in the dissolved phase.** As mentioned earlier, Wauchope (1978) estimates that for most pesticides less than 1% of the material applied is transported in runoff.

Soil and water conservation practices (SWCPS) tend to be more **effective in reducing the movement of sediment** than in reducing the quantity of runoff water. Since most agricultural pesticides are transported partially in the dissolved phase, SWCPS generally are not as effective in reducing the movement of a pesticide as they are in reducing the movement of sediment. An exception is for very strongly adsorbed pesticides like Paraquat, which is usually entirely adsorbed. The effectiveness of SWCPS in reducing pesticide transport is discussed in detail in an earlier report of this project (Shoemaker and Harris, 1979; Steinhuis, 1979; and Beyerlein and Donigian, 1979).

Another way to reduce runoff losses is to use a less persistent pesticide. Pesticides which are persistent are subject to runoff and volatilization for a longer period of time, and thus the quantities of pesticide transported in this fashion tend to be higher.

SECTION 7

CONTROL OF LEACHING LOSSES: WATER MANAGEMENT AND CHOICE OF PESTICIDE

Many pesticides are moderately or strongly adsorbed to soil particles. For such pesticides, transport into groundwater tends to be small because most of the pesticide is filtered by the soil from the leachate as it moves down through the soil column into groundwater. For this reason, **in the past, runoff transport has been considered to be a more important source of pesticide pollution than leaching. However, some of the carbamate pesticides which have come into use more recently are more soluble and more prone toward transport in leachate.** For example, Toxaphene, an organochlorine which has been in use for many years, has a solubility of 3 ppm whereas the solubility of the newer carbamate insecticides, Aldicarb and Carbofuran, are 6000 ppm and 700 ppm, respectively (Finlayson and MacCarthy, 1973). As mentioned earlier, over one-fourth of the wells sampled in a potato-growing region in Long Island had Aldiarb concentrations in excess of the recommended maximum level. The soils on Long Island are sandy and so soil adsorbtion of the Aldicarb is probably less than in many other areas. Carbofuran was also found in some of the wells on Long Island (Severo, 1980). One obvious way to reduce leaching losses is to replace a weakly adsorbed, soluble pesticide with one which is more strongly adsorbed to soil. However, if the alternate pesticide is more persistent or volatile, such substitutions may increase runoff or volatilization losses.

In irrigated crops water management can also reduce leaching losses. **Keeping a soluble pesticide in the root zone where it is subject to microbial degradation and to plant uptake for as long as possible usually decreases leaching losses.** In the period following application of a soluble, weakly adsorbed pesticide, irrigation should be controlled to minimize the movement of water out of the root zone. Similarily, **applying a soluble pesticide during a period of low probability of rainfall can substantially reduce leaching losses.**

SECTION 8

IMPACT OF APPLICATION TIMING ON PESTICIDE TRANSPORT

Weather can have a significant impact on the transport of pesticides. Pesticide applications should be timed to avoid the likelihood of unfavorable weather conditions. For example, **windy conditions can greatly increase drift losses.** Baker and Johnson (1977) found drift losses of 50% in winds of 20 km/hr, from ground applications of a granular insecticide (Fonofos) and of a large droplet spray herbicide (Atrazine). Although such losses are frequently observed for aerial applications, these losses are much higher than would be expected for ground applications in non-windy conditions, especially for granular or large droplet applications. Ware et al., (1972) found that early morning (1.8 mph wind speed) aerial applications of methoxychlor had only 25% drift losses whereas evening applications (3.2 mph wind speed) had 45% drift losses. Since a midafternoon application that occurred under windier conditions (3.6 mph) had less drift (37%) than the evening application, other factors in addition to wind conditions appear to contribute to drift losses.

For nonpersistent pesticides, the amount of material carried by runoff or leaching is very sensitive to the time interval between application and the first significant rainfall. **By changing application timing so that it occurs during a period of low probability of rainfall the expected amount of pesticide transported in runoff can be substantially reduced.** The impact of precipitation can also be reduced by applying pesticides later in the season when the presence of a **crop canopy can reduce the impact of precipitation on runoff transport.**

Although changes in timing of a pesticide application may be a simple and very effective way to reduce pesticide transport, significant changes in timing may not be feasible. The effectiveness of a pesticide application is greatly diminished if it is blown away by wind or washed away by rain. Hence most farmers try to avoid application during weather that is likely to contribute to the movement of a pesticide. However, the farmer's choice of timing may be constrained by other factors. He must avoid applications which are sufficiently close to harvest to cause unacceptable residue levels in the crop. He also may find it difficult to apply pesticides during periods when labor is in short supply. Most importantly, altering the timing may reduce the effectiveness of the pesticide as a pest control agent. For example, runoff losses of a herbicide can often be reduced by replacing pre-emergence treatments with postemergence applications of the herbicide. Unfortunately, this practice is not practical in many cases because the postemergence treatments allow early competition of weeds with the crop and because they require labor at a time which is critical on many farms. **Development of production schedules which are both feasible and economical for the farmer and which result in timings of pesticide applications during dry, nonwindy periods can substantially reduce pesticide transport.**

SECTION 9

REDUCING IMPROPER DISPOSAL

Although extension personnel have for many years distributed information on the proper techniques for disposing of pesticides, the advise is not as widely followed as might be desired. A study by Southern Illinois University discovered that fewer than 20% of the pesticides containers sampled had been properly rinsed and punctured as recommended. One suggestion to remedy this problem is to expand farmer education programs to futher acquaint farmers with proper disposal techniques and with hazards resulting from improper disposal. A more effective measure would be to require a substantial deposit on each pesticide container which would be refunded only when a rinsed, punctured container was brought to a disposal site.

Changes in application equipment may also help to minimize the amount of pesticide entering the environment due to improper disposal. Some spray equipment is designed so that an unopened pesticide container is inserted into an attachment which automatically punctures the can and mixes the pesticide with water. The container is then rinsed. This system insures proper disposal of containers while reducing poisoning risks to the applicator.

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APPENDIX 1

CHARACTERIZATION OF INSECTICIDES

GUIDE TO USE OF INSECTICIDE TABLES

The tables listed in this appendix are designed to aid in the indentification of practices which might be most effective for reducing a specific insecticide pollution problem. **Available information on volatilization, solubility, runoff, drift losses and toxicity is reported for a number of commonly used pesticides. This information is useful in determining which modes of transport are most important to control. The adsorbtion, solubility, volatilization and toxicity data are also useful in assessing the environmental advantages of substituting an alternative insecticide for the one currently in use.** These tables catalogue only insecticides. Unfortunately in the time available for this project it was not possible to also develop tables for the most widely used herbicides and fungicides.

The development of integrated pest management practices which reduce insecticide use depend more upon the crop and its major pest than upon the pesticide being used. As a result, pest management alternatives are not discussed in the tables. Usually the best source of information on available pest management techniques can be provided by extension or research personnel involved in developing pest management programs in the area of concern. Reviews of some of the pest management programs which have been developed in the United States are discussed in the books edited by Huffaker (1980), Metcalf and Luckman (1975) and Pimentel and Smith (1978).

The same format is used for presenting information for each of the pesticides. **The outline below briefly summarizes the significance of each of the factors discussed and its possible impact on the effectiveness of a given alternative for control of pesticide transport.**

A. Nomenclature, Chemical and Physical Properties
   1. Product Name: A single chemical compound may be marketed under several names.

   2. Vapor Pressure: All other factors being equal, volatilization will be higher for pesticides with a higher vapor pressure. For comparison, Toxaphene has a vapor pressure of .2 or .4 mm Hg at 25 C. Nash et al., (1977) measured volatilization losses of toxaphene in an agroecosystem chamber to be 24% of the toxaphene applied to cotton plants at weekly intervals for six

weeks. The rate of application was 2.0 - 2.7 kg/hr per week which is within the range used during cotton pest infestations.

3. Solubility: The propensity of a pesticide to leach and the effectiveness of soil and water conservation practices in part depend upon the partitioning of the pesticide between soil and water. A pesticide's affinity to be absorbed by soil is measured by the adsorption and desorption partition coefficients. Unfortunately the partition coefficients are not published for most pesticides. Solubility values, however, are widely available and are reported here. In most cases, solubility and adsorption are inversely related. Hence, transport by leaching may be a concern for a highly soluble pesticide. Similarily, soil and water conservation practices which reduce the transport of sediment but not the transport of water are in general much more effective in controlling insoluble pesticides than in controlling the transport of soluble pesticides. For example, Aldicarb (solubility: 6000 ppm) has been detected in a large number of wells in Long Island. This has not been true of Toxaphene (solubility: 3 ppm)

B. Use

1. Type: A non-systemic insecticide is designed to make direct contact with the pest. A systemic insecticide is taken up by the plant and has a toxic impact on pests as they feed upon the crop.

2. Primary Crop: Methods like integrated pest management for reducing pesticide use are developed for a particular crop and pest rather than for a particular pesticide. Hence, in order to determine the feasibility of reducing the use of a particular pesticide, it is necessary to know the crops and pest for which it is used.

3. Rates commonly used: The amount of pesticide transported depends in large part on the amount applied.

4. Formulation: Drift losses are highest for dust formulations and lowest for granules. Runoff losses are higher for wettable powders.

C. Behavior in Treated Fields

1. Adsorption and Leaching Characteristics: This section reports the results of investigations studying the adsorption of the pesticide and its impact on transport of the pesticide by leaching.

2. Persistence: The likelihood of transport by runoff, leaching or volatilization is higher for a more persistent pesticide.

3. Runoff Losses: This section is a summary of studies of runoff losses of the pesticide.

D. Behavior in Aquatic Systems

1. Persistence in Water: Pesticides which are persistent in water are more likely to have toxic effects on aquatic organisms than less persistent pesticides of equal toxicity. A higher fraction of the pesticide transported by runoff water is likely to reach a water body for a pesticide which is persistent in water than for a less persistent pesticide with the same adsorption characteristics.

2. Persistance in Submerged Sediments: Submerged sediment can provide a long-term source of the pesticide in the aquatic system.

E. Impact of Aquatic Organisms and

F. Impact on Terristrail Organisms

Toxcity data are very useful in determining the seriousness associated with the transport of a pesticide through a given pathway such as runoff losses. They are also helpful in assessing the advisability of switching to an alternative insecticide. The following abbreviations are used in reporting toxicity results:

LD_{50}, median lethal dose, is the milligrams of toxicant per kilogram of body weight lethal to 50 percent of the test animals to which it is administered under the conditions of the experiment.

LC_{50}, median lethal concentration, is the concentration (ppm or ppb) of toxicant in the environment (usually water) which kills 50 percent of the test organisms exposed.

EC_{50}, median effective concentration, is the concentration (ppm or ppb) of toxicant in the environment (usually water) which produces a designated effect to 50 percent of the test organisms exposed.

TL_m, median tolerance limit, the concentration of chemical in dilution water that kills 50 percent of the test organisms in a given time.

SECTION 1

ALDICARB

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Name: Temik, Ambush.
2. Vapor Pressure at 25°C: 1×10^{-4} mm Hg (USEPA 1975).
3. Solubility in Water at 25°C: 6000 ppm (Finlayson and MacCarthy, 1973).

B. USE

1. Type: Systemic pesticide for use against insects, mites and nematodes.
2. Primary Crops Used on: Cotton, sugar beets, alfalfa, Irish potatoes, corn, peanuts (Eichers _et al_., 1978; USEPA, 1975).
3. Rates Commonly Used: 0.56 to 5.6 kg/ha.
4. Formulations Available: Granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Aldicarb is moderately adsorbed to soil particles. A recent study on the adsorption of several organophosphorus and carbamate insecticides determined relative adsorption capacities (in order of most strongly adsorbed to most weakly adsorbed) to be chlorpyrifos > parathion > terbufos > phorate > aldicarb. Sorption of the pesticides reached equilibrium between solution and soil within 2 hours after application and was positively correlated with organic matter content (Felsot and Dahm, 1979). When aldicarb was incorporated in a sandy loam soil at a rate of 6 kg AI/ha and watered with furrow and sprinkler irrigation in separate plots to simulate both normal and wet growing seasons, residues did leach beyond the 1.3 meter level; however, the researcher noted that concentrations of the total toxic residues were no higher than 100 ppb below the 1.3 meter level (Moorefield, 1974, reported in USEPA, 1975).

2. Persistence: When three soils were treated with 20 ppm of the material, percentages of aldicarb and aldicarb sulfoxide were as follows 12 weeks after application: 0.7% and 95% in clay soil, 42% and 25% in a silty clay loam and 28% and 50% in a fine sand (Coppedge et al., 1967).

3. Runoff Losses: When a bare Norfolk sandy loam field (slope ~ 1%) was treated with an exaggerated rate of 10 lb AI/acre of of aldicarb and disced to a depth of 6 inches immediately after treatment, 8.3 acre-inches of water from sprinkler irrigation and rainfall resulted in only one "analytically significant residue", 140 ppb, which was found in a sample of runoff water taken 8 days after application. No other "analytically significant concentration" was found in runoff water, eroded sediment or pond water taken from the area: the highest concentration of aldicarb found in these samples was 90 ppb (Moorefield, 1974 reported in USEPA, 1975). Although these concentrations may be termed "analytically insignificant", a suggested no-adverse effect level from drinking water of 7 ppb or 0.35 ppb (depending on how much aldicarb is assumed to come from the human diet - NAS, 1977) suggests that these residue levels cannot be dismissed as environmentally insignificant.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: Moorefield (1974 reported in USEPA, 1975) found that aldicarb degraded very little in distilled water or pond and lake water when no bottom material was present. In pond water with 5% mud and lake water with bottom silt half-lives were 5 days and 6 days, respectively. When a farm pond was treated at 3 ppm aldicarb, concentrations declined to 1.1 ppm after 2 weeks, 0.26 ppm after 4 weeks, and 0.06 ppm (the limit of sensitivity for the method) after 6 weeks. When tested in a terrestrial-aquatic model ecosystem aldicarb had high persistence and low biodegradability when compared to other carbamates; oxidation products (sulfoxide and sulfone) were found in the water phase of the system at concentrations of 7.4 ppb (Sangha, 1972).

2. Persistence in Submerged Sediment: When a farm pond was treated at 3 ppm, concentrations in bottom mud peaked at 0.09 ppm 4 weeks after application; the author reported that residues did not build up in sediment and that dissipation of aldicarb residues was rapid and complete (Moorefield, 1974 reported in USEPA, 1975).

E. IMPACT ON AQUATIC ORGANISMS

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Daphnia magna	350 ppb	LC_{50}[1]
FISH		
Rainbow trout	.78-1.6 ppm (48 hr)	LC_{50}[2]
	.62-1.25 ppm (96 hr)	LC_{50}[2]
Channel catfish	1.6 ppm (24 hr)	LC_{50}[3]
	sublethal concentrations	when brain cholinesterase inhibited 80-90%, 6 to 10 days required for 80% recovery of normal activity[3]
	sublethal concentrations	produced scolinosis with[3] localized hemorrhaging
Bluegill sunfish	.175 ppm (48 hr)	LC_{50}[4]
	0.1 ppm (96 hr)	LC_{50}[5]
	4.0 ppm of aldicarb's oxidation product-aldicarb sulfoxide	LC_{50}[5]
	64 ppm of aldicarb's other oxidation product-aldicarb sulfone	LC_{50}[5]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
Mosquito fish and other organisms in terrestrial-aquatic ecosystem (incl. snails, Daphnia, green filamentous algae and mosquito larvae)	----	residues showed low[1] biodegradability when compared to other carbamates

---

[1] Sangha (1972).

[2] Beliles et al. (1966).

[3] Carter (1971).

[4] Knott and Beliles (1966).

[5] Clarkson (1968).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms tested	Concentration of toxin	Results	Reference
BIRDS			
Mallards (5 day old)	594 ppm	LC_{50}	Hill (1974)
Mallards (10 day old)	< 1000 ppm	"	"
Ring-necked pheasant (10 day old)	> 300 ppm	"	"
Japanese quail (14 day old)	381 ppm	"	"
MAMMALS			
Rats	1 mg/kg bw	oral LD_{50}	Ware (1978)
	5 mg/kg bw	dermal LD_{50}	Ware (1978)
Humans	0.001 mg/kg/day	acceptable daily intake	NAS (1977)
	7 µg/1	suggested no-adverse effect level from H_2O - assumption 1	NAS (1977)
	0.35 µg/1	suggested no-adverse effect level from H_2O - assumption 2	NAS (1977)

SECTION 2

AZINPHOSMETHYL

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Guthion, Carfene, DBD, Gusathion, Gusathion M, Methyl Guthion.

2. Vapor Pressure at 20°C: 2.2×10^{-7} mm Hg (Spencer, 1976).

3. Solubility in Water at 25°C: 33 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Non-systemic insecticide and acaricide.

2. Primary Crops Used on: Apples, other fruits and nuts, cotton, Irish potatoes, other vegetables, soybeans, alfalfa (Andrilenas, 1974; Eichers *et al*. 1978).

3. Rates Commonly Used: In 1971 application rates in crops using azinphosmethyl averaged 0.67 kg/ha (Carey *et al*., 1978).

4. Formulations Available: Emulsifiable concentrates, wettable powders, dusts.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Azinphosmethyl is moderately to strongly adsorbed to soil particles. No residues were detected below 38 cm in a sandy loam soil 8 years after its application (Staiff *et al*., 1975).

2. Persistence and Vapor Losses: Fifty percent of the azinphosmethyl applied to Florida muck-sand and Louisiana clay degraded within one month and 3 months, respectively (Anderson *et al*., 1974); when applied to a silt loam, 90% of the material had disappeared after 5 months (Schulz *et al*., 1970). Spencer (1976) reviewed the limited data on azinphosmethyl's potential for vapor losses and concluded that volatilization will occur at a slow rate.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: The degradation of azinphosmethyl follows first-order kinetics and is fairly slow in acid waters. Half-lives at pH 8.6, pH 9.0 and pH 9.5 are 28 days, 30 days and 7 days, respectively; half-life at 45°C and pH 9.5 was less than one day (Heuer et al., 1974). Residues had disappeared from water 2 weeks after treatment when the material was tested as a piscicide at 1 ppm (Meyer, 1965). When azinphosmethyl in water was exposed to UV light (2537 Å) photolytic degradation occurred at pH 10 and pH 11 but not at pH 6 and pH 9; none of the photolytic degradation products that were formed at the higher pH's were insecticidal (Liang and Lichtenstein, 1972).

E. IMPACT ON AQUATIC ORGANISMS

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hrs)	productivity not reduced[1]
Chlorella sp.	1000 ppb	non-toxic[2]
Chlamydomonas sp.	1000 ppb	non-toxic[2]
BENTHIC INVERTEBRATES		
Oligochaetes: *Tubifex tubifex*	1000 ppb (72 hr)	maximum concentration[3] worms could tolerate without mortality
Crustaceans: amphipods-*Gammarus lacustris*	0.56 ppb (24 hr, 21°C)	LC_{50}[4]
	0.25 ppb (48 hr, 21°C)	LC_{50}[4]
	0.15 ppb (96 hr, 21°C)	LC_{50}[4]
Insecta: stonefly naiads-*Pteronarcys californica*	25 ppb (24 hr, 15.5°C)	LC_{50}[5]
	8.0 ppb (48 hr, 15.5°C0	LC_{50}[5]
	1.5 ppb (30 day)	LC_{50}[5]
	1.3 ppb (30 day)	TL_m[6]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Acroneuria pacifica	8.5 ppb (96 hr)	TL_m[6]
FISH		
Rainbow trout	0.049 ppm (24 hr)	LC_{50}[7]
	0.025 ppm (24 hr, 1.6°C)	TL_m[8]
	0.015 ppm (24 hr, 7.2°C)	TL_m[8]
	0.013 ppm (24 hr, 12.7°C)	TL_m[8]
	0.023 ppm (48 hr, 13°C)	LC_{50}[9]
	0.014 ppm (96 hr)	TL_m[10]
Brown trout	0.004 ppm (96 hr)	TL_m[10]
Coho salmon	0.017 ppm (96 hr)	TL_m[10]
Yellow perch	0.013 ppm (96 hr)	TL_m[10]
Red ear sunfish	0.052 ppm (96 hr)	TL_m[10]
Largemouth bass	0.005 ppm (96 hr)	TL_m[10]
Channel catfish	3.30 ppm (96 hr)	TL_m[10]
Channel catfish	1.0 ppm	fish concentrated residues[11] to levels above permissable tolerance levels

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
Goldfish	4.3 ppm (96 hr)	TL_m[10]
Goldfish	0.001 ppm	significant reduction in brain cholinesterase[12]
Fathead minnow	0.24 ppm (96 hr)	TL_m[10]
	0.09 ppm (96 hr)	TL_m[13]
Carp	0.7 ppm (96 hr)	TL_m[10]
	0.2 ppm (96 hr)	LC_{50}[14]
Bluegill sunfish	0.016 ppm (24 hr, 12.7°C)	TL_m[8]
	0.016 ppm (24 hr, 18.3°C)	TL_m[8]
	0.016 ppm (24 hr, 23.8°C)	TL_m[8]
	0.002 ppm (48 hr, 24°C)	TL_m[8]
	0.022 ppm (96 hr)	TL_m[10]
	0.005 ppm (96 hr)	TL_m[13]
Pumpkinseed sunfish	sublethal concentrations	normal brain cholinesterase[15] recovery slow; another exposure 2 weeks later had a cumulative effect

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
Black bullhead	3.5 ppm (96 hr)	TL_m[8]
Guppies	0.11 ppm (96 hr)	TL_m[14]
Harlequin fish	0.13 ppm (24 hr)	LC_{50}[16]
AMPHIBIANS		
Fowler's toad (tadpole)	0.68 ppm (24 hr, 15.5°C)	LC_{50}[17]

[1] Butler (1963).

[2] Loosanoff *et al*. (1957).

[3] Naqvi and Ferguson (1968).

[4] Sanders (1969).

[5] Sanders and Cope (1968).

[6] Jensen and Gaufin (1966).

[7] Cope (1965).

[8] Macek *et al*. (1969).

[9] Cope (1966).

[10] Macek and McAllister (1970).

[11] Meyer (1965).

[12] Weiss and Gakstatter (1964).

[13] Pickering *et al*. (1962).

[14] Lahav and Sarig (1969).

[15] Benke and Murphy (1974).

[16] Alabaster (1969).

[17] Sanders (1970).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organism Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	1900-2000 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	1800-2000 ppm (" " " ")	LC_{50}[1]
Bobwhite Quail	400-500 ppm (" " " ")	LC_{50}[1]
Coturnix Quail	600-700 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	13 mg/kg bw	oral LD_{50}[2]
	220 mg/kg bw	dermal LD_{50}[2]
Humans	0.0025 mg/kg bw	maximum acceptable daily[3] intake
	0.0125 mg/kg/day	acceptable daily intake[4]
	87.5 µg/1	suggested no-adverse effect[4] level from H_2O - assumption 1^2
	4.4 µg/1	suggested no-adverse effect[4] level from H_2O - assumption 1^2

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments: Azinphosmethyl is a ChE inhibitor; psychiatric distrubances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). Azinphosmethyl is readily absorbed from the gastrointestinal tract (Vettorazzi, 1976).

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[1] Heath, R. G. *et al*. (1970a).

[2] Ware, G. W. (1978).

[3] Vettorazzi, G. (1976).

[4] NAS (1977).

SECTION 3

CARBARYL

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Sevin, Hexavin, Karbespray, Ravyon, Septine, Tricarnam.

2. Vapor Pressure at 26°C: < 0.005 mm Hg (Stansburg and Miskus, 1964).

3. Solubility in Water at 30°C: 40 ppm (von Rumker _et al_., 1974).

B. USE

1. Type: Broad spectrum contact insecticide with slight systemic properties.

2. Primary Crops Used on: Soybeans (the use of carbaryl accounted for 46.8% of the 7.9 million pounds of insecticides used in soybeans in 1976), corn (use accounted for 6.6% of the 32.0 million pounds of insecticides used in corn in 1976), tobacco (use acounted for 15.6% of the 3.2 million pounds of insecticides used in tobacco in 1976), peanuts (use accounted for 12.5% of the 2.4 million pounds of insecticides used in peanuts in 1976). Other grains, hay and forage, cotton, alfalfa, vegetables, fruits and nuts (Andrilenas, 1974; Eichers _et al_., 1978).

3. Rates Commonly Used: 1.12 to 2.9 kg/ha, one to ten applications per season; in 1971 application rates in soybeans ranged from 0.90 to 4.30 kg/ha (Carey _et al_., 1978).

4. Formulations Available: Wettable powders, granules, dusts, pellets, sprayables, flowable suspension in non-phytotoxic oil and molasses.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Carbaryl is moderately to strongly adsorbed to soil particles. Haque and Freed (1974) have estimated that leaching will move carbaryl less than 20 cm through loam soil under an annual rainfall of 150 cm; however, when 1000 liters of 3% Sevin were applied to the soil, residues were detected 50 to 60 cm down in the soil profile for 5 to 20 days after the

application (Nalbandyan, 1974).

2. Persistence and Vapor Loss: Insecticidal effectiveness persists for 3 to 10 days on treated plants (von Rumker et al., 1974). The persistence of carbaryl in soil depends on the organic matter content of the soil and pesticide application methods. When carbaryl was applied to soils high in organic matter, half-lives ranged from 2 to 3 days (Alt and Heady, 1977). When carbaryl was banded into corn furrows and incorporated to a 5 cm depth, 135 days were required for a 95% disappearance of residues; broadcast applications resulted in a more rapid degradation of carbaryl (Alt and Heady, 1977). There are indications that volatilization may transport significant amounts of the carbaryl away from treated fields (Lyon and Davidson, 1965). Haque and Freed (1974) have used the best available information to form a vaporization index; according to their estimates, carbaryl may have vapor losses which amount to 3.5 to 14 kg/ha/year or more from a loam soil at 25°C under an annual rainfall of 150 cm.

3. Runoff Losses: When corn grown on a silty loam soil (slope 9.6%) was treated with 5.03 kg/ha of carbaryl, 0.15% of the pesticide was transported away from the field during the 3 months following treatment. (Caro et al., 1974).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: In raw river water (pH 7.3 to 8.0) held at room temperature, 95% of the material disappeared one week after application and no residues were detected after 2 weeks; the suspected degradation product 1-napthol was not detected after the original carbaryl had decomposed (Eichelburger and Lichtenberg, 1971). When the rate of degradation by chemical hydrolysis was tested in a solution having pH's of 7.0 and 9.0, the half-lives were 10.5 days and 2.5 hours, respectively; the degradation product was 1-napthol (Faust and Gomaa, 1972). Aquatic bacteria degrade the 1-napthol while using it as a source of carbon (Paris and Lewis, 1973). The exposure of carbaryl in ETOH or hexane solutions to mercury lamps (2537 Å) or natural light caused the formation of 1-naphthol and several cholinesterase-inhibiting materials (Crosby et al., 1965).

2. Persistence in Submerged Sediment: In sea water, decomposition of carbaryl was slower in the presence of mud than it was in the absence of it (Korinen et al., 1967).

E. IMPACT ON AQUATIC ORGANISMS

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Freshwater algae (several isolates)	0.01 to 25 ppm	increase in inhibition of growth as concentration increased[1]
Chlorella pyrenoidosa	> 0.1 ppm	inhibited growth; inhibition greater at pH 6 than at pH 9[2]
Chlorella pyrenoidosa	-----	no significant effect on growth and photosynthesis[3]
Phaeodactylum tricornutum	0.1 ppm	growth stopped[4]
Monochrysis lutheri	1 ppm	eliminated[4]
Scenedesmus quadricauda	0.1 and 1 ppm	cell number, carbon assimilation and biomass stimulated (the authors predicted that concentrations in aquatic systems would lead to increased algal blooms with subsequent reinforcement of production at all trophic levels)[5]
Oedogonium cardiacum	--- (33 days)	concentrated residue levels in water 127 x's[6]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
algae	-----	bioaccumulation ratio[7] (concentration of chemical in organism to concentration of chemical in water) is 4000
CONSUMERS		
Crustaceans: Cladocerans- *Daphnia pulex*	6.4 ppb (48 hr, 15.5°C)	EC_{50}[8]
Simocephalus serrulatus	7.6 ppb (48 hr, 15.5°C)	EC_{50}[8]
Daphnia magna	-----	no bioaccumulation of[6] original material
BENTHIC INVERTEBRATES		
Oligochaetes: *Tubifex tubifex*	1.5 ppm (72 hr)	maximum concentration[9] worms could tolerate without mortality
Crustaceans: amphipods - *Gammarus lacustris*	40 ppb (24 hr, 21°C)	LC_{50}[10]
	22 ppb (48 hr, 21°C)	LC_{50}[10]
	16 ppb (96 hr, 21°C)	LC_{50}[10]
marine decapods - *Crangon septemspinosa*	0.04 to 0.13 ppm	LC_{50}[11]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
crayfish	-----	bioaccumulation ratio[7] (concentration of chemical in organisms to concentration of chemical in water) is 260
Insecta: stonefly naiads - *Pteronacella badia*	5.0 ppb (24 hr, 15.5°C)	LC$_{50}$[12]
	3.6 ppb (48 hr, 15.5°C)	LC$_{50}$[12]
	1.7 ppb (96 hr, 15.5°C)	LC$_{50}$[12]
Claassenia sabulosa	12 ppb (24 hr, 15.5°C)	LC$_{50}$[12]
	6.8 ppb (48 hr, 15.5°C)	LC$_{50}$[12]
	5.6 ppb (96 hr, 15.5°C)	LC$_{50}$[12]
Pteronarcys californica	30 ppb (24 hr, 15.5°C)	LC$_{50}$[12]
	13 pbb (48 hr, 15.5°C)	LC$_{50}$[12]
	4.8 ppb (96 hr, 15.5°C)	LC$_{50}$[12]
FISH		
Rainbow trout	3.5 ppm (24 hr)	LC$_{50}$[13]
	2.0 ppm (48 hr, 13°C)	LC$_{50}$[14]
	1.04 ppm (96 hr)	LC$_{50}$[15]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Brown trout	1.5 ppm (48 hr)	LC$_{50}$[16]
	2.0 ppm (96 hr)	TL$_m$[17]
Coho salmon	.8 ppm (96 hr)	TL$_m$[17]
Yellow perch	.7 ppm (96 hr	TL$_m$[17]
Red ear sunfish	11.2 ppm (96 hr)	TL$_m$[17]
Largemouth bass	6.4 ppm (96 hr)	TL$_m$[17]
Channel catfish	19 ppm (48 hr, 24°C)	LC$_{50}$[14]
	15.8 ppm (96 hr)	TL$_m$[17]
	----	fish did not accumulate[18] residues; efficient metabolism and excretion of residues
Goldfish	13.2 ppm (96 hr)	"
Fathead minnows	14.6 ppm (96 hr)	"
	0.68 ppm (long-term exposure)	adverse effects on[19] survival and spawning
	0.21-0.68 ppm	maximum acceptable toxi-[19] cant concentrations

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Carp	5.3 ppm (96 hr)	TL_m[17]
Bluegill sunfish	2.5 ppm (48 hr, 24°C)	LC_{50}[14]
	6.8 ppm (96 hr)	TL_m[17]
Black bullhead	20 ppm (96 hr)	TL_m[17]
Harlequin fish	3.4 ppm (24 hr)	LC_{50}[18]
Mosquito fish	----- (3 days)	ratio of residue in fish[6] to residue in water = 0
Fish	----- (1 to 5 mos)	fish grew as well as[19] control fish and had little mortality; however there were massive invasions of the nervous system by a microsporidian parasite

E. IMPACT ON AQUATIC ORGANISMS (Continued)

FOOTNOTES:

[1] Butler *et al*. (1975a).

[2] Christie (1969).

[3] Cole and Platt (1974).

[4] Ukeles (1962).

[5] Stadynk *et al*. (1971).

[6] Sanborn (1974).

[7] Haque *et al*. (1977).

[8] Sanders and Cope (1966).

[9] Naqvi and Ferguson (1968).

[10] Sanders (1969).

[11] Stewart, Milleran and Breese (1967).

[12] Sanders and Cope (1968).

[13] USDI (1963).

[14] Cope (1966).

[15] USDI (1971).

[16] FWPCA (1968)

[17] Macek and McAllister (1970).

[18] Korn (1973).

[19] Carlson (1972).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	> 5000 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	> 5000 ppm (" " " ")	LC_{50}[1]
Bobwhite quail	> 5000 ppm (" " " ")	LC_{50}[1]
Coturnix quail	> 5000 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	307 mg/kg bw	oral LD_{50}[2]
	2000 mg/kg bw	dermal LD_{50}[2]
Humans	0.01 mg/kg bw	maximum acceptable daily[3] intake
	0.082 mg/kg/day	acceptable daily intake[4]
	574 µg/l	suggested no-adverse[4] effect level from H_2O - assumption 1
	28.7 µg/l	suggested no-adverse[4] effect level from H_2O - assumption 2

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments:	Adverse effects on reproductive phsyiology in several animal species and an increased urinary amino acid to acreatinine ratio in humans have been reported (Vettorazzi, 1976). Carbaryl is presently under pre-RPAR review because of possible teratogenicity and fetotoxicity.

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[1] Heath *et al.* (1970a).

[2] Ware (1978).

[3] Vettorazzi (1976).

[4] NAS (1977).

SECTION 4

CARBOFURAN

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Name: Furadan, Curaterr.

2. Vapor Pressure at 33°C: 2×10^{-5} mm Hg (Cook, 1973).

3. Solubility in Water at 25°C: 700 ppm (USEPA, 1976).

B. USE

1. Type: Broad spectrum systemic insecticide, acaricide and miticide.

2. Primary Crops Used on: Corn (the use of carbofuran accounted for 30.9% of the 32 million pounds used in corn in 1976), peanuts (use accounted for 20.8% of the 2.4 million pounds used in peanuts in 1976), alfalfa, rice, sorghum, soybeans, tobacco, wheat (Andrilenas, 1974; Eichers _et al_., 1978).

3. Rates Commonly Used: 1.0 to 5.6 kg/ha, one application per season for soil treatments, one to two applications per season for foliar treatment; in 1971 application rates in field corn ranged from 0.28 to 2.58 kg/ha (Carey _et al_., 1978).

4. Formulations Available: Granules, flowable paste, wettable powder.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Carbofuran is moderately adsorbed to soil particles. Field studies in a Nebraska fallow field and a Georgia tobacco field indicated that residues generally remain in the upper 30 cm (USEPA, 1976).

2. Persistence and Vapor Losses: Carbofuran's persistence in soils varies greatly depending on manner of application, soil pH and microbial populations. The half-life of the material was 117 days when furrow applications were made on an acidic heavy textured soil; broadcast applications on a more neutral soil resulted in a half-life of 46 days (Caro _et al_., 1973). High microbial activity in a soil can reduce the persistence and insecticidal effectiveness of

carbofuran (Williams et al., 1976) while in other areas degradation can be so slow as to cause a build-up of residues after 2 successive years of treatment (Williams and Brown, 1976). Studies have shown that 50% of the carbofuran hydrolyzes to its phenol in 30 days; the phenol then becomes an unextractable residue with a half-life for extractability of about 7 days (Knaak, 1971). No data was available on vapor losses (Spencer, 1976).

3. Runoff Losses: Caro et al. (1973) studied carbofuran in runoff from a silty loam soil with soil treatments by broadcast and in-furrow applications and reported losses of 0.5 to 2.0 percent of the original material. Although the carbofuran applied as an in-furrow treatment persisted for a longer period of time (117 days versus 46 days for the broadcast material), runoff losses were less for a given volume of runoff when in-furrow applications were used. Runoff losses were transported primarily in the dissolved phase of the runoff and were higher after the granules had dissolved and released the active ingredient. Smith et al. (1974) have studied loss of carbofuran from conventionally tilled corn grown on claypan soils and found larger runoff losses than those reported from silty loam soils. Carbofuran was applied at a rate of 1.12 kg AI/ha, and suffered single event runoff losses which ranged from zero to 10.73 g/ha in 1971, 32.4 to 56.6 g/ha in 1972, and zero to 161.5 g/ha in 1973. Maximum single event losses in each year in terms of a percentage of the material applied consisted of .96 percent in 1971, 5.05 percent in 1972, and 14.42 percent in 1973; maximum concentrations in water ranged from 298 to 600 ppb in the three years of the study. Lysimeter studies have indicated that 20 to 30 times more carbofuran is transported in the dissolved phase than in the sediment phase of the runoff (von Rumker et al., 1974). It has been shown by Smith et al. (1974) that on claypan soils the runoff losses of carbofuran from corn grown under conventional tillage will be equal to, or smaller than the runoff losses from corn grown under conservation and no tillage production systems. Conservation tillage methods which reduce water runoff may be more successful in reducing runoff losses of carbofuran from soils lacking claypans.

The FMC Corporation has conducted runoff studies (reported in USEPA, 1976), and found carbofuran residues of 1 ppm in a neighboring pond when heavy rainfall followed four days after corn treatment with 4.48 kg AI/ha. This contamination was reduced to "negligible" concentrations by the time the next sample was taken sixteen days later. As the 96 hour LC_{50} for ten fish species range 0.08 to 1.18 ppm, (Pimentel, 1971), these runoff losses constitute a serious threat to non-target species.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: Studies in model ecosystems have shown that carbofuran hydrolyzes rapidly in aquatic systems (Yu et al., 1974)

and degrades to water soluble materials which do not persist or remain at high levels (Sanborn, 1974). Applications to flooded rice fields showed maximum concentrations 14 hours after application whereupon residues quickly dissipated, having a half-life of one day or less (USEPA, 1976).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Scenedesmus sp.	100 ppm	inhibited[1]
Chlorella sp.	100 ppm	inhibited[1]
Anhistrodesmus sp.	100 ppm	inhibited[1]
Euglena sp.	100 ppm	inhibited[1]
CONSUMERS		
Crustaceans: cladocerans- *Daphnia magna*	20 ppb	LC_{50}[2]
Daphnia magna	---	no bioaccumulation of[3] original material
BENTHIC INVERTEBRATES		
Crustaceans: pink shrimp - *Penaeus duorarum*	6.8 ppb (24 hr)	EC_{50}[4]
	4.6 ppb (48 hr)	EC_{50}[4]
Insecta: mosquito larvae	---	no bioaccumulation of[3] original material

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature	Results
FISH		
Rainbow trout	1.8 ppm	hyperactivity[5]
	3.2 ppm	hyperactivity, increased[5] respiration and intermittent loss of equilibrium
	4 ppm granules (96 hr)	TL_m[5]
	.28 ppm technical (96 hr)	TL_m[5]
Brown trout (city water)	0.355 ppm (24 hr)	LC_{50}[6]
(standard water)	0.842 ppm (24 hr)	LC_{50}[6]
(city water)	0.28 ppm (96 hr)	LC_{50}[6]
(standard water)	0.56 ppm (96 hr)	LC_{50}[6]
Coho salmon	0.53 ppm (24 hr)	LC_{50}[6]
	0.524 ppm (96 hr)	LC_{50}[6]
Yellow perch	0.15 ppm (24 hr)	LC_{50}[6]
	0.147 ppm (96 hr)	LC_{50}[6]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Organism Tested		
Channel catfish	2.03 ppm (24 hr)	LC_{50}[7]
	4.1 ppm granules (96 hr)	TL_m[5]
	.21 ppm technical (96 hr)	TL_m[5]
	1.8 ppm	hypoactivity, increased respiration and intermittent loss of equilibrium[5]
Fathead minnow	1.32 ppm (24 hr)	LC_{50}[6]
	1.18 ppm (96 hr)	LC_{50}[6]
Bluegill sunfish	2.3 ppm granules (96 hr)	TL_m[5]
	.24 ppm technical (96 hr)	TL_m[5]
	1.8 ppm	hypoactivity, increased respiration, intermittent loss of equilibrium, intermittent flacidity and intermittent convulsions[5]
Mosquito fish	--- (3 days)	ratio of residues in fish to residues in water = 0[8]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
AMPHIBIANS		
Bullfrog (tadpole)	2.7 ppm (96 hr)	LC_{50}[9]

[1] Christie (1969).
[2] Sangha (1972).
[3] Sanborn (1974).
[4] Lowe (1970).
[5] Schoenig (1967).
[6] Mauck (1972).
[7] Carter (1971).
[8] Metcalf *et al* (1973).
[9] Carter and Graves (1973).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin	Results
BIRDS		
Young mallards	0.40 mg/kg bw	LD$_{50}$[1] (oral dose in capsule)
Young pheasant	4.2 mg/kg bw	LD$_{50}$[1] (oral dose in capsule)
Young bobwhite quail	5.0 mg/kg bw	LD$_{50}$[1] (oral dose in capsule)
Young fulvous ducks	0.24 mg/kg bw	LD$_{50}$[1] (oral dose in capsule)
MAMMALS		
Rats	8 mg/kg bw	oral LD$_{50}$[2]
	10200 mg/kg bw	dermal LD$_{50}$[2]

Other Comments: Carbofuran is a acetylcholinesterase inhibitor (Yu *et al.*, 1972).

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[1] Tucker and Crabtree (1970).

[2] Ware (1978).

SECTION 5

DIAZINON

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Spectracide, G-24480, Dasudin, Diazajet, Diazide, Diazol, Dazzel, Gardentox.

2. Vapor Pressure at 20°C: 1.4×10^{-4} mm Hg (Sanborn *et al.*, 1977).

3. Solubility in Water at Room Temperature: 40 ppm (Sanborn *et al.*, 1977).

B. USE

1. Type: Broad spectrum, non-systemic insecticide with some acaricidal action.

2. Primary Crops Used on: Alfalfa (the use of diazinon accounted for 11.1% of the 5.4 million pounds of insecticides used in alfalfa in 1976); corn, wheat, sorghum, soybeans, cotton, tobacco, vegetables, and other field crops (Andrilenas, 1974; Eichers *et al.*, 1978).

3. Rates Commonly Used: In 1971 application rates in crops using diazinon averaged 0.84 kg/ha; rates in field corn 0.01 to 2.80 kg/ha (Carey *et al.*, 1978).

4. Formulations Available: Wettable powder, dust, emulsifiable concentrate, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Diazinon is moderately to strongly adsorbed to soil particles. Haque and Freed (1974) have estimated that leaching will move diazinon less than 20 cm through a loam soil under an annual rainfall of 150 cm; however, in 17.8 cm soil columns diazinon was more mobile than phorate, disulfoton, the triazine herbicides and the chlorinated hydrocarbon insecticides (Harris, 1969).

2. Persistence and Vapor Losses: Insecticidal effectiveness persists for 7 to 10 days on treated foliage (von Rumker *et al.*, 1974). The

half-lives of diazinon in peaty loam and in a loam soil were 35 days and 20 to 40 days, respectively (Suett, 1971; Bro-Rasmussen _et al_., 1968); 85% of the diazinon applied to a silt loam had disappeared after 140 days (Getzin, 1967). Spencer (1976) has reviewed the limited data on diazinon's vapor losses and has concluded that diazinon will volatilize slowly from various substrates; however, Haque and Freed (1974) have estimated that diazinon may have vapor losses amounting to 3.5 to 6.5 kg/ha/year or more from a loam soil at 25°C under an annual rainfall of 150 cm.

3. Runoff Losses: In the Bradfield Marsh in Ontario, where the use of diazinon has replaced the use of DDT for carrot fly control, runoff water in ditches draining the black soils contained diazinon residues in every sample taken from April to October of 1972; maximum concentrations of 1070 ppb, 680 ppb and 2040 ppb were seen in early July, late August and the middle of October, respectively (Harris and Miles, 1975).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: Paris and Lewis (1973) considered hydrolysis to be diazinon's major degradation mechanism; diazinon's rate constant of hydrolysis (and half-life?) at 20°C and pH 7.4 is 4435.8 hours (~ 184 days) whereas the rate constant of hydrolysis of the major metabolite, diazoxon, is 693.5 hours (~ 29 days) (Faust and Gomaa, 1972). Water from rice fields which had been repeatedly treated with diazinon did mineralize residues within 4 days (Sethunathan and Pathak, 1971, 1972). The component of the system responsible for this degradation was inactivated by streptomycin; strains of _Flavobacterium_ and _Arthrobacter_ were isolated from the water. Diazinon applied to a cranberry bog at initial concentrations of 0.32 ppm disappeared completely within 144 hours (Miller _et al_., 1966). When diazinon was exposed to UV light hydroxydiazinon was formed (Paris and Lewis, 1973).

2. Persistence in Submerged Sediment: When diazinon was applied to rice fields in the Phillipines, concentrations of the pyrimidine hydrolysis product exceeded concentrations of diazinon 12 days after application (Sethunathan and Yoshida, 1969); the pyrimidine ring was further degraded to CO_2 (Sethunathan and MacCrae, 1969).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hrs)	productivity reduced[1] by 7%
Three blue-green algae	400 ppm	tolerated concentrations[2]
Freshwater plankton	0.01 to 25 ppm	inhibited growth[3]
Scenedesmus quadricauda	-----	no significant impact on[4] cell number, photosynthesis or biomass
CONSUMERS		
Crustaceans: cladocerans- *Daphnia pulex*	0.90 ppb (48 hr, 15.6°C)	EC_{50}[5]
Daphnia magna	4.3 ppb (50 hr, 68°F)	EC_{50}[5]
Daphnia carinata	0.8 ppb (32 hr, 78°F)	EC_{50}[5]
Simocephalus serrulatus	1.8 ppb (48 hr, 15.6°C)	EC_{50}[5]
BENTHIC INVERTEBRATES		
Crustaceans: amphipod - *Gammarus lacustris*	800 ppb (24 hr, 21°C)	LC_{50}[6]
	500 ppb (48 hr, 21°C)	LC_{50}[6]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Crustaceans: amphipod - Gammarus lacustris	200 ppb (96 hr, 21°C)	LC_{50}[6]
Insecta: stonefly naiads - Pteronarcys californica	155 ppb (48 hr, 21°C)	LC_{50}[7]
	60 ppb (48 hr, 15.5°C)	LC_{50}[7]
	25 ppb (96 hr, 15.5°C)	LC_{50}[7]
mosquito larvae - Culex fatigans	83 ppb (24 hr)	LC_{50}[8]
FISH		
Rainbow trout	0.38 ppm (24 hr, 55°F)	LC_{50}[9]
	0.17 ppm (48 hr)	LC_{50}[9]
	0.9 ppm (96 hr)	LC_{50}[10]
Bluegill sunfish	0.052 ppm (24 hr, 75°F)	LC_{50}[9]
	0.03 ppm (48 hr)	LC_{50}[11]
	0.022 ppm (96 hr)	LC_{50}[10]
Harlequin fish	1.45 ppm (24 hr)	LC_{50}[12]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxic (exposure time and temperature)	Results
Mummichog (minnow)	0.3 ppm	concentrated residues in water 10 fold; 50% residues in tissues lost in less than 1 week when fish placed in clean water[13]

[1] Butler (1963).

[2] Singh (1973).

[3] Butler *et al*. (1975a).

[4] Stadynk *et al*. (1971).

[5] Sanders and Cope (1966).

[6] Sanders (1969).

[7] Sanders and Cope (1968).

[8] W.H.O. (1968).

[9] Cope (1965).

[10] USDI (1965).

[11] FWPCA (1968).

[12] Alabaster (1969).

[13] Miller *et al*. (1966).

F. IMPACT ON TERRESTRIAL ORGANISM

Organisms Tested	Concentration of toxin	Results
BIRDS		
Young mallards	3.5 mg/kg bw	LD_{50}[1] (oral dose in capsule)
Young pheasants	4.3 mg/kg bw	LD_{50}[1] (oral dose in capsule)
MAMMALS		
Rat	66 mg/kg/ bw	oral LD_{50}[2]
	379 mg/kg bw	dermal LD_{50}[2]
Human	0.002 mg/kg/day	acceptable daily intake[3]
	14.0 μg/1	suggested no-adverse[3] effect level from H_2O - assumption 1
	0.7 μg/1	suggested no-adverse[3] effect level from H_2O - assumption 2

Other Comments: Diazinon is a ChE inhibitor; psychiatric disturbances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over period of 1-1/2 to 10 years (Gershon and Shaw, 1961). Diazinon is excreted in the urine and feces at a fairly rapid rate and does not persist or accumulate in tissues or organs (Vettorazzi, 1976).

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[1] Tucker and Crabtree (1970). [2] Ware (1978). [3] NAS (1977).

SECTION 6

DIMETHOATE

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Cygon, Dimetate, De-Fend, Perfekthion, Rogor
2. Vapor Pressure at 25°C: 8.5×10^{-6} mm Hg (Martin and Worthing, 1977).
3. Solubility in Water at 21°C: 25000 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Broad spectrum contact and systemic insecticide and acaricide.
2. Primary Crops Used on: Sorghum, corn, cotton, wheat, alfalfa, soybeans, tobacco (Eichers *et al*., 1978).
3. Formulations Available: Emulsifiable concentrates, ultralow volume, wettable powders, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Dimethoate is moderately adsorbed to soil particles, Haque and Freed (1974) have estimated that leaching will move dimethoate more than 35 cm through a loam soil under an annual rainfall of 150 cm.

2. Persistence and Vapor Losses: When applied to a loam soil at the rate of 1.8 lb/A, dimethoate's half-life in soil was 11 days (Bro-Rasmussen *et al*., 1970); applications to a sandy loam soil resulted in a half-life of 4 days when no rain fell after application and a half-life of 2.5 days when application was followed by moderate rainfall (Bohn, 1964). In a Coachella fine sand, dimethoate persisted for less than 2 months as tested by *Hippelates collusor* larvae (Mulla *et al*., 1961; Mulla, 1966). It has been reported that dimethoate is metabolized to dimethoxon in soil (Bache and Lisk, 1966; Duff and Menzer, 1973). Haque and Freed (1974) have used the best available information to form a vaporization index; according to their estimates, dimethoate may have vapor losses which amount to 0.2 to 3.0 kg/ha/year or more from a

loam soil at 25°C under an annual rainfall of 150 cm.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: When dimethoate was added to raw river water (pH 7.3 to 8.0) held at room temperature, 50% of the residues disappeared in eight weeks (Eichelberger and Lichtenberg, 1971).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Marine phytoplankton	---	growth much more inhibited[1] by organochlorine insecticides than by organophosphorus insecticides
Estaurine phytoplankton	1000 ppb (4 hr)	average inhibition of[2] 75.3% for 12 organochlorine insecticides tested; only 5 out of 13 organophosphorus insecticides caused reductions in excess of 10% (average inhibition = 25.5%)
CONSUMERS		
Crustaceans: cladocerans- Daphnia magna	2500 ppb (48-50 hr)	LC_{50}[3]
BENTHIC INVERTEBRATES		
Crustaceans: amphipods - *Gammarus lacustris*	900 ppb (24 hr, 21°C)	LC_{50}[4]
	400 ppb (48 hr, 21°C)	LC_{50}[4]
	200 ppb (96 hr, 21°C)	LC_{50}[4]

E IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Crustaceans: brown shrimp - *Crangon crangon*	0.3 to 1 ppb (48 hr)	LC_{50}[5]
Insecta: stonefly naiad - *Pteronarcys californica*	510 ppb (24 hr, 15.5°C)	LC_{50}[6]
	140 ppb (48 hr, 15.5°C)	
	43 ppb (96 hr, 15.5°C)	LC_{50}[6]
FISH		
Rainbow trout	19 ppm (24 hr)	LC_{50}[7]
	8.5 ppm (96 hr)	LC_{50}[8]
Bluegill sunfish	28 ppm (96 hr)	LC_{50}[9]
	9.6 ppm (48 hr)	LC_{50}[3]
	6.0 ppm (96 hr)	LC_{50}[10]

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[1] Ukeles (1962).

[2] Butler (1963) in Hurlbert (1975).

[3] F.W.P.C.A. (1968).

[4] Sanders (1969)

[5] Portmann and Wilson (1971).

[6] Sanders and Cope (1968).

[7] Alabaster (1969).

[8] USDI (1964).

[9] Cope (1965).

[10] USDI (1965).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	900-1100 ppm (5 days treated feed followed by 3 days clean feed)	LC$_{50}$[1]
Pheasants	300-400 ppm (" " " ")	LC$_{50}$[1]
Coturnix quail	300-400 ppm (" " " ")	LC$_{50}$[1]
MAMMALS		
Rats	250 mg/kg bw	oral LD$_{50}$[2]
	150 mg/kg bw	dermal LD$_{50}$[2]
Humans	0.02 mg/kg bw	maximum acceptable daily[3] intake

Other Comments: Dimethoate is a ChE inhibitor; psychiatric disturbances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). Although dimethoate is rapidly absorbed from the digestive tract, accumulation does not occur in fat tissues and elimination is rapid in rats and humans (Vettorazzi, 1976).

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[1] Heath *et al*. (1970). [2] Ware (1978). [3] Vettorazzi (1976).

SECTION 7

DISULFOTON

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Di-Syston, Bay 19639, Dithiodemeton, Dithiosytox, Frumin AL, Solvirex, Thiodemeton.
2. Vapor Pressure at 20°C: 1.8 mm Hg (Sanborn et al., 1977).
3. Solubility in Water at 20°C: 25 ppm (Sanborn et al., 1977).

B. USE

1. Type: Systemic insecticide and acaricide.
2. Primary Crops Used on: Wheat (the use of disulfoton accounted for 25.0% of the 7.2 million pounds of insecticides used in wheat in 1976); sorghum, (use accounted for 23.9% of the 4.6 million pounds used in sorghum in 1976); cotton, soybeans, tobacco, corn, alfalfa, peanuts, Irish potatoes (Andrilenas, 1974; Eichers et al., 1978).
3. Rates Commonly Used: 0.33 to 5.6 kg/ha, one to three applications each season; in 1971 rates in cotton ranged from 0.01 to 7.85 kg/ha (Carey et al., 1978).
4. Formulations Available: Water soluble powder, wettable powders, water soluble liquid, dust, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Disulfoton is strongly adsorbed to soil particles. Studies in a 17.8 cm soil column have indicated that disulfoton is only slightly mobile within soil (Harris, 1969).
2. Persistence: Disulfoton's half-life in soil ran from 40 to 100 days (von Rumker et al., 1974).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Submerged Sediments: Disulfoton is degraded more

rapidly in flooded or anaerobic soils than in upland or aerobic soils; the major metabolite resulting from the oxidation is disulfoton sulfoxide (Takase et al., 1972).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hr)	ethion, naled and disulfoton[1] caused 50 to 70% decreases in productivity
BENTHIC INVERTEBRATES		
Crustaceans: amphipods - Gammarus lacustris	110 ppb (24 hr, 21°C)	LC$_{50}$[2]
	70 ppb (48 hr, 21°C)	LC$_{50}$[2]
	52 ppb (96 hr, 21°C)	LC$_{50}$[2]
Insecta: stonefly naiads - Acroneuria pacifica	9.4 ppb (5 day, 12.0°C)	TL$_m$[3]
	1.4 ppb (30 day, 12.0°C)	TL$_m$[3]
Pteronarcys californica	40 ppb (24 hr, 15.5°C)	LC$_{50}$[4]
	18 ppb (48 hr, 15.5°C)	LC$_{50}$[4]
	5.0 ppb (96 hr, 15.5°C)	LC$_{50}$[4]
	24 ppb (5 day, 12.8°C)	TL$_m$[3]
	1.9 ppb (30 day, 12.8°C)	TL$_m$[3]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentrations of toxins (exposure time and temperature)	Results
FISH		
Goldfish	6.5 ppm (96 hr)	TL_m[5]
Fathead minnow	3.7 ppm (96 hr)	TL_m[5]
Bluegill sunfish	0.04 ppm (48 hr)	LC_{50}[6]
Bluegill sunfish	0.06 ppm (96 hr)	TL_m[5]
Guppies	0.25 ppm (96 hr)	TL_m[5]

[1] Butler (1963).

[2] Sanders (1969).

[3] Jensen and Gaufin (1966).

[4] Sanders and Cope (1968).

[5] Pickering et al. (1962)

[6] F.W.P.C.A. (1968).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	400-600 ppm (5 days treated feed followed by 3 days clean feed)	LC$_{50}$[1]
Pheasants	600-700 ppm (" " " ")	LC$_{50}$[1]
Bobwhite quail	700-800 ppm (" " " ")	LC$_{50}$[1]
Coturnix	300-400 ppm (" " " ")	LC$_{50}$[1]
MAMMALS		
Rats	2 mg/kg bw	oral LD$_{50}$[2]
	20 mg/kg bw	dermal LD$_{50}$[2]
Humans	0.001 mg/kg bw	maximum acceptable[3] daily intake
	0.0001 mg/kg bw	acceptable daily[4] intake
	0.7 g/1	suggested no-adverse[4] effect level from H_2O - assumption 1
	0.035 g/1	suggested no-adverse[4] effect level from H_2O - assumption 2

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments:	Disulfoton is a ChE inhibitor; psychiatric disturbances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). Toxicological studies indicate that disulfoton has no effect on reproduction and does not have teratogenic or mutagenic properties (Vettorazzi, 1976).

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[1] Heath _et_ _al_. (1970).

[2] Ware (1978).

[3] Vettorazzi (1976).

[4] NAS (1977).

SECTION 8

ENDOSULFAN

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Thiodan, Chlorthiepin, Cyclodan, Insectophene, Kop-Thion, Malic, Malix, Thifor, Thimal.
2. Vapor Pressure at 25°C: 1×10^{-5} mm Hg (Martin and Worthing, 1977).
3. Solubility in Water: < 1 ppm (Sanborn *et al.*, 1977).

B. USE

1. Type: Non-systemic contact and stomach insecticide.
2. Primary Crops Used on: Cotton, alfalfa, Irish potatoes, other vegetables, tobacco, apples, other fruits and nuts, other field crops (Andrilenas, 1974; Eichers *et al.*, 1978).
3. Rates Commonly Used: In 1971 application rates in crops using endosulfan averaged 1.6 kg/ha; rates in Michigan ranged up to 6.72 kg/ha (Carey *et al.*, 1978).
4. Formulations Available: Emulsifiable concentrates, wettable powders, dusts, granules, ultralow volume.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Endosulfan is very strongly adsorbed to soil particles. When applied to soil at 6.7 kg/ha, 90% of the material leached no further than the top 15 cm; 9% was recovered from the zone of 15 to 30 cm (Stewart and Cairns, 1974).
2. Persistence: Half-life on plants is three to seven days for most fruits and vegetables (Martin and Worthing, 1977). When endosulfan was applied to soil at a rate of 6.7 kg/ha, the *alpha* and *beta* isomers took 60 and 800 days, respectively for 50% conversion to endosulfan sulfate (Stewart and Cairns, 1974). Studies on the persistence of endosulfan sulfate were not carried out; however, the authors defined it as "relatively stable" and equally toxic to insects.

3. Runoff Losses: When potatoes grown on a gravelly loam (slope 8%) were treated with 1.05 kg/ha of endosulfan, 0.3% of the pesticide was transported away from the field during the 3 months following treatment (Epstein and Grant, 1968).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: When endosulfan was added to raw river water (pH 7.3 to 8.0) containing colloidal material but kept aerobic, concentrations of the two active isomers were reduced by 70% within one week; 8 weeks after application complete degradation of both isomers had occurred (Eichelburger and Lichtenberg, 1971). It has been estimated that endosulfan will have a half-life of 5 weeks in water at pH 7 and a half-life of 5 months at pH 5 (Greve and Witt, 1971).

2. Persistence in Submerged Sediment: The ratio of adsorbed to free insecticide is 4:1 when endosulfan is added to a turbid aqueous suspension (Richardson and Epstein, 1971).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hrs)	productivity reduced by 87%[1]
Chlorella vulgaris	0.2 ppm	reduced rate of reproduction[2]
CONSUMERS		
Crustaceans: cladocerans - Daphnia pulex	240 ppb (48 hr)	TL$_m$[3]
Daphnia magna	52.9 ppb (96 hr)	LC$_{50}$[4]
BENTHIC INVERTEBRATES		
Crustaceans: amphipods - Gammarus lacustris	9.2 ppb (24 hr, 21°C)	LC$_{50}$[5]
	6.4 ppb (48 hr, 21°C)	LC$_{50}$[5]
	5.8 ppb (96 hr, 21°C)	LC$_{50}$[5]
Gammarus fasciatus	6.0 ppb (96 hr, 21°C)	LC$_{50}$[5]
Insecta: stonefly naiad - Pteronarcys californica	24 ppb (24 hr, 15.5°C)	LC$_{50}$[6]
	5.6 ppb (48 hr, 15.5°C)	LC$_{50}$[6]
	2.3 ppb (96 hr, 15.5°C)	LC$_{50}$[6]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organism Tested	Concentration of toxin (exposure time and temperature)	Results
FISH		
Rainbow trout	13 ppb (24 hr, 1.6°C)	TL_m[7]
	6.1 ppb (24 hr, 7.2°C)	TL_m[7]
	3.2 ppb (24 hr, 12.7°C)	TL_m[7]
	1.2 ppb (48 hr)	LC_{50}[8]
	2.6 ppb (96 hr, 1.6°C)	TL_m[7]
	1.7 ppb (96 hr, 7.2°C)	TL_m[7]
	1.5 ppb (96 hr, 12.7°C)	TL_m[7]
Harlequin fish	0.02 ppb (24 hr)	LC_{50}[8]

[1] Butler (1963).

[2] Knauf and Schulze (1973).

[3] F.W.P.C.A. (1968).

[4] Schoettger (1970).

[5] Sanders (1969)

[6] Sanders and Cope (1968).

[7] Macek _et al_. (1969).

[8] Alabaster (1969).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	900 - 1100 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	1200 - 1350 ppm (" " " ")	LC_{50}[1]
Bobwhite quail	800 - 900 ppm (" " " ")	LC_{50}[1]
Coturnix quail	2100 - 2250 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	18 mg/kg bw	oral LD_{50}[2]
	74 mg/kg bw	dermal LD_{50}[2]
Humans	0.0075 mg/kg bw	maximum acceptable[3] daily intake for endosulfan A, endosulfan B and endosulfan sulfate

Other Comments: Studies on several species of animals indicate that endosulfan does not have cumulative properties (Vettorazzi, 1975).

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[1] Heath *et al*. (1970).

[2] Ware (1978).

[3] Vettorazzi (1975).

SECTION 9

EPN

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: EPN

2. Vapor Pressure at 100°C: 3×10^{-4} mm Hg (Martin and Worthing, 1977).

3. Solubility in Water: Insoluble (Gunther et al., 1968).

B. USE

1. Type: Non-systemic insecticide and acaricide with contact and stomach action with a broad range of activity.

2. Primary Crops Used on: Cotton (the use of EPN accounted for 9.5% of the 64.1 million pounds of insecticides used on cotton in 1976); corn, soybeans (Eichers et al., 1978).

3. Formulations Available: Emulsifiable concentrates, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: EPN's small degree of solubility in water would lead one to expect very little movement of residues by leaching.

2. Persistence: When EPN was applied to the soil, residues persisted for less than 3 years (Terriere and Ingalsbe, 1953). When EPN was applied at 11.2 kg/ha and incorporated to a depth of 6 inches, concentrations of 0.2 ppm were detected by bioassay one year later. This rate of degradation works out to a half-life of approximately 10 weeks (Alt and Heady, 1977).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence: No information was available on the degradation of EPN in water and submerged sediments (see FONOFOS for general information on the persistence of organophosphates in aquatic systems).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Marine phytoplankton	-----	growth much more inhibited[1] by organochlorine insecticides than by organophosphorus insecticides (EPN not tested)
Estaurine phytoplankton	1000 ppb (4 hr)	average inhibition of[2] 75.3% for 12 organochlorines, insecticides tested; only 5 out of 13 organophosphorus insecticides caused reduction in excess of 10% (average inhibition = 25.5%) EPN not tested.
CONSUMERS		
Crustaceans: cladocerans - *Daphnia pulex* (zooplankton)	148 ppb (48 hr, 15.6°C)	average EC_{50} for 12[3] organochlorines tested
	1.7 ppb (48 hr, 15.6°C)	average EC_{50} for 10[3] organophosphorus compounds tested (EPN not tested)

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
BENTHIC INVERTEBRATES		
Crustaceans: amphipods - *Gammarus lacustris*	15 ppb (96 hr, 21°C)	LC_{50}[4]
Gammarus fasciatus	7 ppb (96 hr)	LC_{50}[5]
Insecta: mosquito larvae - *Culex fatigans*	4.4 ppb (24 hr)	LC_{50}[6]
FISH		
Goldfish	0.45 ppm (96 hr)	TL_m[7]
Fathead minnows	0.25 ppm (96 hr)	TL_m[7]
Bluegill sunfish	0.1 ppm (96 hr)	TL_m[7]
Guppies	0.03 ppm (96 hr)	TL_m[7]
Golden shiners	sublethal concentrations of malathion and EPN	acted synergistically in terms of cholinesterase inhibition.[8]

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[1] Ukeles (1962).

[2] Butler (1963) in Hurlbert (1975).

[3] Sanders and Cope (1966).

[4] Sanders (1969).

[5] USEPA (1973).

[6] W.H.O. (1968).

[7] Pickering *et al*. (1962).

[8] Weiss (1959).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Young mallards	3.1 mg/kg bw	LD_{50} (oral dose in capsule)[1]
Pheasants	950-1150 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[2]
Bobwhite quail	300-350 ppm (" " " ")	LC_{50}[2]
Coturnix quail	250-300 ppm (" " " ")	LC_{50}[2]
MAMMALS		
Rats	7 mg/kg bw	oral LD_{50}[3]
	22 mg/kg bw	dermal LD_{50}[3]

Other Comments: EPN is a ChE inhibitor; psychiatric disturbances have been noted in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). EPN is presently undergoing pre-RPAR review because of possible neurotoxicity.

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[1] Tucker and Crabtree (1970).

[2] Heath *et al*. (1970).

[3] Ware (1978).

SECTION 10

FONOFOS

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Dyfonate

2. Vapor Pressure at 25°C: 2.1×10^{-4} mm Hg (Martin and Worthing, 1977).

3. Solubility in Water at 25°C: 13 ppm (Wauchope, 1978).

B. USE

1. Type: Insecticide particularly effective for control soil insects.

2. Primary Crops Used on: Corn (the use of Fonofos accounted for 15.6% of the 320 million pounds of insecticides used in corn in 1976); peanuts (Eichers et al., 1970).

3. Rates Commonly Used: In 1971 application rates on corn averaged 1.01 kg/ha (Carey et al., 1978).

4. Formulations Available: Granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: When fonofos granules were band applied and incorporated to a maximum depth of 5 cm, residues remained primarily in the top 10 cm of the soil profile (Baker and Johnson, 1979).

2. Persistance and Vapor Losses: Fonofos had a half-life of 22 weeks in a peaty loam high in organic matter and cation exchange capacity; in a sandy loam low in both organic matter and cation exchange capacity, the half-life of fonofos was more than 50% shorter (Suett, 1971). When fonofos was applied as an emulsion at a rate of 11.2 kg/ha and incorporated ot a depth of 5 to 6 inches, residues had a half-life of 20 days (Schulz and Lichtenstein, 1971). However non-extractable bound residues have been found and indicate that fonofos may be more persistent than was previously thought. Lichtenstein et al. (1977) tested an agricultural loam soil for fonofos residues and found that after 28 days, 47% of the applied fonofos existed as extractable residues and an additional 35%

existed as extractable residues. Lichtenstein and Schulz (1970) studied the relative volatilities of various pesticides and found that approximately 0.96% of the parathion, 0.63% of the diazinon, 16.3% of the fonofos and less than 0.01% of the azinphosmethyl volatilized from soil incubated at 30°C whereas 26.1%, 11.5%, 1.32% and 0.78% of the aldrin, lindane, dieldrin and DDT volatilized in the same period of time.

3. Runoff Losses: When continuous corn grown on a silt loam soil (slope 12 to 18%) with conventional tillage systems was treated with 1.12 kg/ha active ingredient of fonofos, an average of 0.21 and 0.15% of the pesticide was lost with sediment and water, respectively. The conservation tillage method of ridge-plant reduced runoff losses relative to conventional tillage by 77% whereas the conservation tillage method of till-plant resulted in average runoff losses of 107% of those seen with conventional tillage (Baker and Johnson, 1979).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence: No data was available on the persistence of fonofos in aquatic systems. There is some disagreement about the degradation of organophosphates in water and sediment. While some have asserted that this group of insecticides generally hydrolyze within 8 to 12 days in water and sediments having pH's ranging from 6.0 to 8.5 (Muirhead-Thomson, 1971; Pionke and Chesters, 1973), others have predicted that in temperature conditions (zero to 25°C) and pH values (pH 5.5 to 8.5) of natural waters, organophosphates are quite persistent (Faust and Gomaa, 1972).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Marine phytoplankton	----	growth much more inhibited[1] by organochlorine insecticides than by organophosphorus insecticides (FONOFOS not tested)
Estaurine phytoplankton communities	1000 ppb (4 hr)	average inhibition of[2] 75.3% for 12 organochlorine insecticides tested; only 5 of 13 organophosphorus insecticides caused reductions in excess of 10% (average inhibition = 25.5%) FONOFOS not tested
CONSUMERS		
Crustaceans: cladocerans - Daphnia pulex (Zooplankton)	148 ppb (48 hr, 15.6°C)	average EC_{50} for 12 organochlorines tested[3]
	1.7 ppb (48 hr, 15.6°C)	average EC_{50} for 10 organophosphorus compounds tested[3] (FONOFOS not tested)

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH		
Rainbow trout	0.11 ppm (24 hr)	LC_{50}[4]
Bluegill sunfish	0.045 ppm (24 hr)	LC_{50}[4]

[1] Ukeles (1962).

[2] Butler (1963) in Hurlbert (1975).

[3] Sanders and Cope (1966).

[4] Edwards (1977).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin	Results
MAMMALS		
Rats	8 mg/kg bw	oral LD_{50}[1]
	147 mg/kg bw	dermal LD_{50}[1]

[1] Ware (1978).

SECTION 11

MALATHION

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Cythion, Emmatos, Emmatos Extra, Fyfanon, Karbofos, Kop-thion, Kypfos, Malaspray, Malamar, MLT, Zithiol.

2. Vapor Pressure at 30°C: 4×10^{-5} mm Hg (Sanborn et al., 1977).

3. Solubility in Water at Room Temperature: 145 ppm (Sanborn et al., 1977).

B. USE

1. Type: Broad spectrum nonsystemic insecticide and acaricide.

2. Primary Crops Used on: Alfalfa (the use of malathion accounted for 14.8% of the 5.4 million pounds of insecticides used in alfalfa in 1976); sorghum, tobacco, wheat, rice, peanuts, cotton, fruits and nuts, vegetables (Andrilenas, 1974; Eichers et al., 1974).

3. Rates Commonly Used: 0.6 to 4.48 kg/ha, one to ten applications each season; in 1971 rates in cotton 0.78 to 2.69 kg/ha (Carey et al., 1978).

4. Formulations Available: Ultralow volume,emulsifiable concentrate, wettable powder.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Malathion is moderately adsorbed to soil particles- adsorption is positively correlated with organic matter content, humic acid content and cation exchange capacity (MacNamara and Toth, 1970). Haque and Freed (1974) have estimated that leaching will move malathion more than 35 cm through a loam soil under an annual rainfall of 150 cm; however the likelihood of groundwater contamination is small because malathion residues reaching the soil surface (the material is not applied to the soil) degrade very rapidly (von Rumker et al., 1974).

2. Persistence and Vapor Losses: Insecticidal effectiveness persists for 1 to 3 days on most treated crops (von Rumker et al., 1974). When malathion was sprayed on ladino clover and exposed to UV light at 37°C, 66% of the residues disappeared in 16 hours (Archer, 1971). Fifty percent of the malathion applied to clay soil and silty clay loam and 90% of the malathion applied to loamy sand degraded within 24 hours (Konrad et al., 1969). Spencer (1976) reviewed the limited data on malathion's vapor losses and concluded that accurate predictions about potential volatility in field conditions could not be made because of the lack of data. Haque and Freed (1974) have used the best available information to form a vaporization index; according to their estimates, malathion may have vapor losses which amount to 0.2 to 3.0 kg/ha/year or more from a loam soil at 25°C under an annual rainfall of 150 cm.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: The persistence of malathion in water depends to a large extent on the pH of the solution. Residues resist degradation by chemical hydrolysis in neutral and acid waters but are readily degraded by aquatic bacteria (such as Pseudomones, Xanthomonas, Comanonas and Flavobacterium) which hydrolyze off one of the ethyl groups of the succinyl-ester side chain (Paris et al., 1975) creating malathion β-monoacid along with some diethyl maleate (Zepp et al., 1975). In raw river water (pH 7.3 to 8.0) held at room temperature malathion was degraded within 4 weeks (the metabolites of this degradation were not identified); when this same test was run in distilled water no hydrolysis occurred (Eichelburger and Lichtenberg, 1971; USEPA, 1973). Chemical hydrolysis occurs fairly rapidly in waters having a pH above 7.0; malathion had a half-life of one week in a solution of pH 8 (Weiss and Gakstatter, 1965) and hydrolyzed almost immediately at pH 12 (Spiller, 1961). Diethyl fumarate is a product of chemical hydrolysis (Weiss and Gakstatter, 1965) and is twice as toxic as malathion for fathead minnows (Bender, 1969). In Sawannee River water containing large amounts of colored material the photolytic half-life (wavelengths > 290 nm) of malathion was 16 hours; photolytic half-life was 990 hours in clear water at pH 6 (Wolfe et al., 1975).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hrs)	productivity reduced by 7%[1]
Planktonic algae	1 to 50 ppm	only at 25 ppm and 50 ppm did growth inhibition occur[2]
Algae	-----	degraded malathion in presence of light-only degradation product isolated-malathion β-monoacid[3]
Chlorella sp.	-----	no effect on growth and $^{14}CO_2$ fixation irrespective of inoculum size and sampling time[4]
Chlorella pyrenoidosa	6% TDE/6% malathion	inhibition of growth[5]
Chlorella pyrenoidosa	10% BHC/29% malathion	inhibition of growth[5]
Chlorella pyrenoidosa	-----	inhibited growth slightly at both pH 6.5 and 9.0, inhibition decreased with time[6]
Euglena gracilis (cells)	0.15 to 7.25 ppm	inhibition only at highest concentrations[7]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Euglena gracilis	10 to 100 ppm	stimulation of growth[8]
CONSUMERS		
Crustaceans: cladocerans -		
Daphnia pulex	1.8 ppb (48 hr, 15.6°C)	EC_{50}[9]
Daphnia magna	0.9 ppb (50 hr, 68°F)	EC_{50}[9]
Daphnia carinata	0.2 ppb (64 hr, 78°F)	EC_{50}[9]
Simocephalus serrulatus	3.5 ppb (48 hr, 15.6°C)	EC_{50}[9]
BENTHIC INVERTEBRATES		
Crustaceans: amphipod -		
Gammarus lacustris	3.8 ppb (24 hr, 21°C)	LC_{50}[10]
	1.8 ppb (48 hr, 21°C)	LC_{50}[10]
	1.0 ppb (96 hr, 21°C)	LC_{50}[10]
: marine decapods -		
Crangon septemspinosa	33 ppb (96 hr, 20°C)	LC_{50}[11]
Palaemonetes vulgaris	82 ppb (96 hr, 20°C)	LC_{50}[11]
Pagurus longicarpus	83 ppb (96 hr, 20°C)	LC_{50}[11]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Crustaceans: snails -	------	no bioaccumulation of parent compound[12]
Insecta: stonefly naiads - Pteronarcella badia	10 ppb (24 hr, 15.5°C)	LC$_{50}$[13]
	6.0 ppb (48 hr, 15.5°C)	LC$_{50}$[13]
	1.1 ppb (96 hr, 15.5°C)	LC$_{50}$[13]
Claassenia sabulosa	13 ppb (24 hr, 15.5°C)	LC$_{50}$[13]
	6.0 ppb (48 hr, 15.5°C)	LC$_{50}$[13]
	2.8 ppb (96 hr, 15.5°C)	LC$_{50}$[13]
Pteronarcys californica	35 ppb (24 hr, 15.5°C)	LC$_{50}$[14]
	20 ppb (48 hr, 15.5°C)	LC$_{50}$[13]
	10 ppb (96 hr, 15.5°C)	LC$_{50}$[13]
	8.8 ppb (30 day, 12.8°C)	TL$_m$[14]
Acroneuria pacifica	7.7 ppb (5 day, 12.8°C)	TL$_m$[14]
	0.78 ppb (30 day, 12.8°C)	TL$_m$[14]
: mosquito larvae - Culex fatigans	80 ppb (24 hr)	LC$_{50}$[15]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Anopholes albimanus	320 ppb (24 hr)	LC$_{50}$[16]
: caddisflies - *Arctopsyche grandis*	32 ppb (96 hr, 51-54°C)	LC$_{50}$[17]
Hydropsyche californica	22.5 ppb (96 hr, 51-54°C)	LC$_{50}$[17]
: mayflies - *Ephemerella grandis*	100 ppb (96 hr, 48-50°F)	LC$_{50}$[17]
Baetis sp.	6 ppb (48 hr, 21°C)	LC$_{50}$[18]
FISH		
Rainbow trout	0.1 ppm (24 hr, 45°F)	LC$_{50}$[19]
	0.085 ppm (24 hr, 55°F)	LC$_{50}$[19]
	0.13 ppm (24 hr, 65°F)	LC$_{50}$[19]
	0.079 ppm (48 hr, 45°F)	LC$_{50}$[19]
	0.07 ppm (48 hr, 45°F)	LC$_{50}$[19]
	0.12 ppm (48 hr, 65°F)	LC$_{50}$[19]
	0.170 ppm (96 hr)	TL$_{m}$[20]
Brown trout	0.200 ppm (96 hr)	TL$_{m}$[20]
Coho salmon	0.101 ppm (96 hr)	TL$_{m}$[20]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Yellow perch	0.263 ppm (96 hr)	TL_m[20]
Red ear sunfish	0.17 ppm (96 hr)	TL_m[20]
Largemouth bass	0.285 ppm (96 hr)	TL_m[20]
Channel catfish	8.97 ppm (96 hr)	TL_m[20]
Channel catfish	10.7 ppm (96 hr)	TL_m[20]
Goldfish	0.45 ppm (96 hr)	TL_m[21]
Goldfish	0.001 ppm (96 hr)	significant reduction in cholinesterase; recovery 1 mo later when placed in clean water[22]
Fathead minnows	8.65 ppm (96 hr)	TL_m[20]
Fathead minnows	$\geq$ 0.002 ppm (10 mos)	abnormal F_1 production[23]
Fathead minnows	chemical hydrolysis product diethyl fumarate (produced when water is notably acidic)	diethyl fumarate twice as toxic as malathion; more toxic in presence of malathion than alone.[22,24]
Carp	6.6 ppm (96 hr)	LC_{50}[20]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Carp	0.005 ppm (4 days)	accumulated 28 ppm in flesh and 2.5 ppm in brain; after 4 days in clean water residues in body < 1 ppm[25]
Bluegill sunfish	0.220 ppm (24 hr, 12.7°C)	TL_m[26]
	0.140 ppm (24 hr, 18.3°C)	TL_m[26]
	0.110 ppm (24 hr, 23.8°C)	TL_m[26]
	0.086 ppm (48 hr, 24°C)	LC_{50}[18]
	0.103 ppm (96 hr)	TL_m[20]
Bluegill sunfish	> 0.020 ppm	deleterious to spawning[27]
	0.010 ppm	33% of offspring developed[27] spinal deformations, thus,
	0.0035 - 0.0075 ppm	maximum acceptable toxic[27] concentration in water
Black bullhead	12.9 ppm (96 hr)	TL_m[20]
Guppies	0.84 ppm (96 hr)	TL_m[21]
Harlequin fish	10 ppm (24 hr)	LC_{50}[28]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Golden shiners	sublethal doses malathion and EPN	act synergistically in terms of cholinesterase inhibition[29]
Fish	----	half-life in flesh = < 1 day[30]
AMPHIBIANS		
Fowler's toad (tadpole)	1.9 ppm (24 hr, 15.5°C)	LC_{50}[31]
Western Chorus toad (tadpole)	.56 ppm (24 hr, 15.5°C)	LC_{50}[31]

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[1] Butler (1963).

[2] Butler et al. (1975b).

[3] Aldrige et al. (1976).

[4] Ellis and Goulding (1973).

[5] Gloyna and Thirumurth (1967).

[6] Christie (1969).

[7] Moore (1970).

[8] Poorman (1973).

[9] Sanders and Cope (1966).

[10] Sanders (1969).

[11] Eisler (1969).

[12] Metcalf and Sanborn (1975).

[13] Sanders and Cope (1968).

[14] Jensen and Gaufin (1966).

[15] W.H.O. (1968).

[16] Georghiou (1972).

[17] Gaufin et al. (1965)

[18] Cope (1966).

[19] Cope (1965).

[20] Macek and McAllister (1970).

[21] Pickering et al. (1962).

[22] Weiss and Gakstatter (1964).

[23] Mount and Stephan (1967).

[24] Bender (1969).

[25] Brown (1961).

[26] Macek et al. (1969).

[27] Eaton (1970).

[28] Alabaster (1969).

[29] Weiss (1959).

[30] Macek (1970).

[31] Sanders (1970).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxic (exposure time and temperature)	Results
BIRDS		
Mallards	> 5000 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	2500-4500 ppm (" " " ")	LC_{50}[1]
Bobwhite quail	3300-3700 ppm (" " " ")	LC_{50}[1]
Coturnix quail	2000-2300 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	885 mg/kg bw	oral LD_{50}[2]
	4000 mg/kg bw	dermal LD_{50}[2]
Humans	0.02 mg/kg/day	acceptable daily intake[3]
	140 µg/l	suggested no-adverse effect[3] level from H_2O - assumption 1
	7.0 µg/l	suggested no-adverse effect[3] level from H_2O - assumption 2

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments: Malathion is an indirect inhibitor of ChE; psychiatric distrubances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). Toxicity to mammals is low and storage in animal tissues does not occur to any significant degree (Vettorazzi, 1976).

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[1] Heath *et al*. (1970a).

[2] Ware (1978).

[3] NAS (1977).

SECTION 12

METHOMYL

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Lannate.
2. Vapor Pressure at 38°C: 4.0×10^{-5} mm Hg (Spencer, 1976).
3. Solubility in Water at 25°C: 58000 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Foliar treatment and systemic when mixed in soil.
2. Primary Crops Used on: Tobacco (the use of methomyl accounted for 21.9% of the 3.2 million pounds of insecticides used in tobacco in 1976); peanuts (use accounted for 25.0% of the 2.4 million pounds used in peanuts in 1976); cotton, soybeans, alfalfa, Irish potatoes, other vegetables (Andrilenas, 1974; Eichers *et al*., 1978),
3. Rates Commonly Used: In 1971 application rates in crops using methomyl averaged 1.27 kg/ha (Carey *et al*., 1978).
4. Formulations Available: Water soluble powder, wettable powder, water soluble liquid, dusts, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: No leaching data, distribution coefficients or Freundlich adsorption coefficients were found for methomyl.
2. Persistence: Laboratory and field studies show that methomyl has a half-life of less than 30 to 42 days; some of the disappearance may be due to incorporation into soil organic matter (Kaufman, 1976).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: No data was found specifically on the persistence of methomyl in water; however the carbamate insecticides, though less persistent than the organophosphates, do not degrade

rapidly by chemical hydrolysis in conditions of temperature (zero to 25°C) and pH values (5.5 to 8.5) found in aquatic environments (Faust and Gomaa, 1972). When five carbamate insecticides were added to raw river water (pH 7.3 to 8.0) and held at room temperature, degradation was fairly rapid; carbaryl and Zectran and their suspected degradation products disappeared from the water in two weeks time whereas Matacil, Mesurol and Mesurol's decomposition product 4-methyl-thio-3,5-dimethyl phenol disappeared in four weeks time. Ninety-five percent of the Baygon degraded in eight weeks; Baygon's phenol was not detected after eight weeks (Eichelberger and Lichtenberg, 1971).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH		
Rainbow trout	3.4 ppm (96 hr)	TL_m[1]
Goldfish	> 0.1 ppm (96 hr)	TL_m[1]
Bluegill sunfish	0.87 ppm (96 hr)	TL_m[1]

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[1] Martin and Worthing (1977).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin	Results
BIRDS		
Young Mallards	15.9 mg/kg bw	LD_{50} (oral dose in capsule)[1]
MAMMALS		
Rats	17 mg/kg bw	oral LD_{50}[2]
	1000 mg/kg bw	dermal LD_{50}[2]

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[1] Tucker and Crabtree (1970).

[2] Ware (1978).

SECTION 13

METHOXYCHLOR

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Marlate, Dianisyltrichloroethane, Dimethoxy-DT, DMDT, Methoxy-DDT.

2. Vapor Pressure: No data found (Spencer, 1976).

3. Solubility in Water at 25°C: 0.10 ppm (Freed, 1976).

B. USE

1. Type: Non-systemic contact and stomach insecticide with little aphicidal or acaricidal activity.

2. Primary Crops Used on: Alfalfa (the use of methoxychlor accounted for 25.9% of the 5.4 million pounds of insecticides used on alfalfa in 1976); other hay and pasture, tobacco, corn, peanuts, other field crops, fruits, nuts, potatoes and other vegetables (Andrilenas, 1974; Eichers *et al*., 1978).

3. Rates Commonly Used: In 1971 application rates in crops using methoxychlor averaged 0.19 kg/ha; rates ranged from 0.01 to 0.02 kg/ha in field corn (Carey *et al*., 1978).

4. Formulations Available: Wettable powders, emulsifiable concentrates, dusts, aerosols.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Methoxychlor is very strongly adsorbed to soil particles. When applied to soil surface, 95 to 97% of the residues leached no further than the top 10 cm; the remaining percentage migrated as much as 100 cm through the soil profile (Obuchowska, 1972).

2. Persistence: Methoxychlor applied to soil at a rate of 2 mg/100 gm soil persisted for 20 to 38 weeks; persistence was inversely related to soil moisture levels (Obuchowska, 1969).

3. Runoff Losses: When grass grown on a silty clay loam (slope 0.2%) was treated with 22.5 kg/ha of methoxychlor, 0.0047% of the pesticide was transported away from the field during the 14 months following treatment (Edwards and Glass, 1971).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: In water, methoxychlor declined from application concentrations of 1.5 mg/liter to 0.5 mg/liter after 155 to 169 days; a further decline in concentration was not observed between 169 and 460 days (Luczak, 1969). Bender and Eisele (1971) predicted that methoxychlor would persist for 2 to 7 days if biological degradation was the major mode of degradation and 200 days if hydrolysis was the major mode. Further studies have shown that if chemical hydrolysis is the only mode of degradation, methoxychlor's half-life in water is one year; the degradation products of hydrolysis are anisoin (the major product) which hydrolyzes faster than methoxychlor and DMDE which hydrolyzes slower than methoxychlor (Wolfe et al., 1977). When concentrations of 0.1 to 0.2 ppm methoxychlor in water were exposed to ultraviolet light approximately 50% of the methoxychlor decomposed to form 2 metabolites in one week; 90% of the methoxychlor decomposed in one month (Paris and Lewis, 1973).

2. Persistence in Submerged Sediment: The ratio of adsorbed to free insecticide was 10:1 when methoxychlor was added to a turbid aqueous suspension (Richardson and Epstein, 1971); however, when methoxychlor was added to pond water at a concentration of 0.04 ppm, residues were not found in the bottom sediments (Kennedy et al., 1970). Methoxychlor persisted for one to more than three months in four different flooded Phillipine soils (Castro and Yoshida, 1971).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Estaurine phytoplankton	1000 ppb (4 hrs)	productivity reduced by[1] 80%
Algae	-------	did not inhibit growth[2,3,4,5] but was removed from culture by algae
Algal filaments	20 ppm	killed in five days[6]
Aerobacter aerogenes	0.5 to 5.0 μg/liter	both accumulated residues[7] directly from H_2O - bacterial levels reached 1,400 to 4,300 x's levels found in water
Bacillus subtilis		
CONSUMERS		
Protozoa	20 ppm	killed immediately[6]
Crustaceans: cladocerans - *Daphnia pulex*	0.78 ppb (48 hr, 15.6°C)	EC_{50}[8]
Daphnia magna	3.7 ppb (24 hr, 68°F)	EC_{50}[8]
Simocephalus serrulatus	5 ppb (48 hr, 15.6°C)	EC_{50}[8]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
BENTHIC INVERTEBRATES		
Oligochaetes: *Asellus aquaticus*	0.001 ppm	toxic[9]
: *Lumbriculus viviegatus*	0.44 ppm	toxic[9]
Crustaceans: amphipods - *Gammarus lacustris*	2.9 ppb (24 hr, 21°C)	LC_{50}[10]
	1.3 ppb (48 hr, 21°C)	LC_{50}[10]
	0.8 ppb (96 hr, 21°C)	LC_{50}[10]
marine decapods - *Crangon septemspinosa*	4 ppb (96 hr, 20°C)	LC_{50}[11]
Palaemonetes vulgaris	12 ppb (96 hr, 20°C)	LC_{50}[11]
Paqurus longicarpus	1 ppb (96 hr, 20°C)	LC_{50}[11]
Insecta: stonefly naiad - *Pteronarcys californica*	30 ppb (24 hr, 15.5°C)	LC_{50}[12]
	8.0 ppb (48 hr, 15.5°C)	LC_{50}[12]
	1.4 ppb (96 hr, 15.5°C)	LC_{50}[12]
mosquito larvae - *Culex fatigans*	67 ppb (24 hr)	LC_{50}[13]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Insecta: damselfly naiads (Coenagrionidae)	0.01 and 0.04 ppm	population depressed for two weeks[14]
mayfly (Heptageniid)	0.04 ppm	insects absent for two weeks after treatment; after 84 days only recovered to 40% of control population[14]
mayfly (Baetid)	0.04 ppm	populations slightly depressed[14]
FISH		
Rainbow trout	55 ppb (24 hr, 1.6°C)	TL_m[15]
	45 ppb (24 hr, 7.2°C)	TL_m[15]
	74 ppb (24 hr, 12.7°C)	TL_m[15]
	30 ppb (96 hr, 1.6°C)	TL_m[15]
	42 ppb (96 hr, 7.2°C)	TL_m[15]
	62 ppb (96 hr, 12.7°C)	TL_m[15]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Brook trout	5 ppb	bioconcentrated to 1759 ppb in 7 days; when placed in fresh water lost 41.3% of residues in one week[16]
Yellow perch	10 ppb (96 hr)	all killed[17]
	0.625 ppb (96 hr)	growth retarded[17]
Goldfish	56 ppb (96 hr)	TL_m[18]
Fathead minnow	64 ppb (96 hr)	TL_m[18]
	8.63 ppb (96 hr)	TL_{50}[17]
	1 ppb (96 hr)	hatching of eggs inhibited[17]
	2 ppb (96 hr)	hatching of eggs completely inhibited[17]
Bluegill sunfish	58 ppb (24 hr, 12.7°C)	TL_m[15]
	67 ppb (24 hr, 18.3°C)	TL_m[15]
	83 ppb (24 hr, 23.8°C)	TL_m[15]
	53 ppb (96 hr)	TL_m[15]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Bluegill sunfish	-----	residues in tissues disappeared in 2 mos[14]
Guppies	120 ppb (96 hr)	TL_m[18]
Mosquito fish	-----	~ 15% of the fish surviving an exposure which caused low mortalities (19-40%) aborted their young[19]
Mosquito fish	---- (3 days)	in a terrestrial-aquatic ecosystem, ratio of residue in fish to residue in water = 1550:1[20]
Fish	----	residues in fish had a half-life of approximately one week[21]
Fish	----	residues in fish disappeared in 17 days[22]
AMPHIBIANS		
Fowler's toad (tadpole)	760 ppb (24 hr, 15.5°C)	LC_{50}[23]
Western Chorus frog (tadpole)	440 ppb (24 hr, 15.5°C)	LC_{50}[23]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

[1] Butler, 1963.

[2] Butler *et al*. (1975a).

[3] Krichner *et al*. (1975).

[4] Poorman (1973).

[5] Butler *et al*. (1975a).

[6] Cabejszik and Stanislawska (1965).

[7] Johnson and Kennedy (1973).

[8] Sanders and Cope (1966).

[9] Lakota (1974).

[10] Sanders (1969).

[11] Eisler (1969).

[12] Sanders and Cope (1968).

[13] W.H.O. (1968).

[14] Kennedy *et al*. (1970).

[15] Macek *et al*. (1969).

[16] Burdick *et al*. (1968).

[17] Merna and Eisele (1973).

[18] Henderson *et al*. (1959).

[19] Boyd (1964).

[20] Metcalf *et al*. (1971).

[21] Macek (1970).

[22] Fredeen *et al*. (1975).

[23] Sanders (1970).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	> 5000 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	> 5000 ppm (" " " ")	LC_{50}[1]
Bobwhite quail	> 5000 ppm (" " " ")	LC_{50}[1]
Coturnix quail	> 5000 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	5000 mg/kg bw	oral LD_{50}[2]
	2820 mg/kg bw	dermal LD_{50}[2]
Humans	0.1 mg/kg/day	acceptable daily intake[3]
	700 µg/1	suggested no-adverse[3] effect level from H_2O - assumption 1
	35.0 µg/1	suggested no-adverse[3] effect level from H_2O - assumption 2

Other Comments: Methoxychlor's rapid detoxication in the liver yields a metabolite which is excreted into the intestine and removed from the body in the feces; low mammalian oral toxicity and low tissue storage result from this complete and rapid metabolism (Vettorazzi, 1975).

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

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[1] Heath _et al_. (1970).

[2] Ware (1978).

[3] NAS (1977).

SECTION 14

METHYL PARATHION

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Dalf, Folidal M, Metron, Metacide, Nitrox 80, Panton M, Bladan M, Tekwaisa, E 601, Metaphor, Folidol 80, Wofatox.

2. Vapor Pressure at 20°C: 0.97×10^{-5} mm Hg (Martin and Worthing, 1977).

3. Solubility in Water at 25°C: 55 to 60 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Broad-spectrum, non-systemic insecticide.

2. Primary Crops Used on: Cotton (the use of methyl parathion accounted for 31.2% of the 6.41 million pounds of insecticides used in cotton in 1976); wheat (use accounted for 16.7% of the 7.2 million pounds of insecticides used in wheat in 1976); soybeans, corn, sorghum, other grains, alfalfa (Andrilenas, 1974; Eichers et al., 1978).

3. Rates Commonly Used: In 1971 application rates in crops using methyl parathion averaged 3.15 kg/ha; rates in cotton ranged from 0.06 to 11.21 kg/ha (Carey et al., 1978).

4. Formulations Available: Emulsifiable concentrate, wettable powders, dust.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Methyl parathion is strongly adsorbed to soil particles. Li and Fleck (1972) have reported presence of small amounts (in parts per trillion range) of the material in surface and subsurface rain effluents. Haque and Freed (1974) have estimated that leaching will move methyl parathion less than 20 cm through a loam soil udner an annual rainfall of 150 cm.

2. Persistence and Vapor Losses: Methyl parathion has a short residual life on treated plants; in midsummer, applied concentrations of

106 ppm may fall to 3.9 ppm 96 hours after application (Ware et al. 1972). When the material was applied to a Carrington silt loam only 8% of the residues remained 15 days after treatment (Lichtenstein and Schulz, 1964). Later studies by Lichtenstein et al. (1977) have shown, however, that while only 7% of the applied methyl parathion was extractable 28 days after soil treatment, 43% of the applied material persisted in the form of nonextractable bound residues. These bound residues are apparently not excluded from environmental interactions (Fuhremann and Lichtenstein, 1978). Spencer (1976) has reviewed the data on methyl parathion's vapor losses and has concluded that vaporization is an important pathway of dissipation from treated fields. Haque and Freed (1974) have used the best available information to form a vaporization index; according to their estimates, methyl parathion may have vapor losses amounting 7 to 14 kg/ha/year from a loam soil at 25°C under an annual rainfall of 150 cm. Methyl parathion has been detected in air samples from Alabama, Florida and Mississippi (Stanley et al., 1971); the maximum residue level of methyl parathion found in the air above the Mississippi Delta was 2060 ng/m^3, a level which was 313 and 1315 ng/m^3 higher than the detected maximum residue levels of toxaphene and DDT, respectively (Arthur, 1976). Methyl parathion has also been found in indoor and outdoor air samples taken from pesticide formulators' homes (Tessari and Spencer, 1971).

3. Runoff Losses: When four different plots of cotton grown on loamy sand and sandy loam soils (slopes of 4% and 2%, respectively) were treated with 13.4 kg/ha of methyl parathion, 0.008 to 0.25% of the pesticide was transported away from the field during the 4 to 6 months following treatment (Sheets et al., 1972).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: Eichelberger and Lichtenberg (1971) found that methyl parathion degraded completely in bottled raw river water (pH 7.3 to 8.0) within 8 weeks and USEPA (1975) reported that persistence of less than 4 months in lake water. Apperson et al. (1976) in a study on Clear Lake found a carry over of methyl parathion residues from treatment-to-treatment when the material was applied at intervals of 20 days.

2. Persistence in Submerged Sediments: When Clear Lake was treated with methyl parathion in the absence of residues in sediment samples suggested that degradation took place before or upon penetration of the bottom mud (Apperson et al., 1976).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Marine phytoplankton	----	growth much more inhibited by organochlorine insecticides than by organophosphorus insecticides[1]
Estaurine phytoplankton	1000 ppb (4 hr)	average inhibition of[1] 75.3% for 12 organochlorine insecticides tested; only 5 out of 13 organophosphorus insecticides caused reductions in excess of 10% (average inhibition = 25.5%) methyl parathion not tested
Anabaena (blue-green algae responsible for intoxicating and killing livestock and wildlife on farm ponds)	3 successive applications of 3 ppb	heavy blooms resulted because of reductions in Daphnia, Cyclops and Diaptomus[2]
CONSUMERS		
Crustaceans: cladocerans - Daphnia magna	4.8 ppb (48 hr)	TL_m[3]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
BENTHIC INVERTEBRATES		
Oligochaetes: *Tubifex tubifex*	6 ppm (72 hr)	maximum concentrations[4] worms could tolerate without mortality
Crustaceans: Marine decapods - *Crangon septemspinosa*	2 ppb (96 h5, 20°C)	LC_{50}[5]
Palaemonetes vulgaris	3 ppb (96 hr, 20°C)	LC_{50}[5]
Pagarus longicarpus	5 ppb (96 hr, 20°C)	LC_{50}[5]
: Freshwater shrimp- *Palaemonetes radiakensis*	2.5-23.3 (24 hr, 21-27°C)	LC_{50}[6]
: Grass shrimp - *Palaemonetes pugio*	sublethal concentrations	impair ability of shrimp to[7] escape predation by gulf killifish *Fundulus grandis*
: Grass shrimp - *Palaemonetes pugio*	sublethal concentrations	predator gulf killifish[8] consumed a greater proportion of grass shrimp when prey species (shrimp and the less susceptible juvenile sheepshead minnows) were exposed to sublethal concentrations; author suggested that altered species composition & species diversity could result

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Crustaceans: red crayfish - *Procambarus clarkii*	10 ppt (5 days)	LC_{80}[9]
Procambarus clarkii	50 ppb (24 hr, 16-32°C)	TL_m[10]
Procambarus clarkii	40 ppb (48 hr, 16-32°C)	TL_m[10]
Procambarus clarkii	40 ppb (96 hr, 16-32°C)	TL_m[10]
Insecta: mosquito larvae - *Culex fatigans*	18 ppb (24 hr)	LC_{50}[11]
Anopheles albimanus	6.5 ppb (24 hr)	LC_{50}[12]
FISH		
Rainbow trout	2.8 ppm (96 hr)	TL_m[13]
Brown trout	4.7 ppm (96 hr)	TL_m[13]
Spotted sea trout	---	59 ppb found in ovaries;[14] concentration of toxin not given
Coho salmon	5.3 ppm (96 hr)	TL_m[13]
Yellow perch	3.1 ppm (96 hr)	TL_m[13]
Red ear sunfish	5.2 ppm (96 hr)	TL_m[13]
Largemouth bass	5.2 ppm (96 hr)	TL_m[13]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxic (exposure time and temperature)	Results
Channel catfish	5.7 ppm (96 hr)	TL_m[13]
Goldfish	9.0 ppm (96 hr)	TL_m[13]
Fathead minnow	8.9 ppm (96 hr)	TL_m[13]
Carp	7.1 ppm (96 hr)	TL_m[13]
Bluegill sunfish	8 ppm (48 hr)	LC_{50}[3]
	5.7 ppm (96 hr)	LC_{50}[13]
Black bullhead	6.6 ppm (96 hr)	LC_{50}[13]
Guppies	7.8 ppm (96 hr)	LC_{50}[13]
Puffer	sublethal concentrations	physiological changes[16]
Marine fish	----	very low toxicity[17]
Fish	sublethal concentrations	induces abortion[18]
Fish	concentrations much lower than short term LC_{50}	inhibit brain cholinesterase[14]

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[1] Ukeles (1962).

[2] Cook and Connors (1963).

[3] F.W.P.C.A. (1968).

[4] Naqvi and Ferguson (1968).

[5] Eisler (1969).

[6] Nagvi and Fergusion (1970).

[7] Farr (1977).

[8] Farr (1978).

[9] Hendrick _et_ _al_. (1966).

E. IMPACT ON AQUATIC ORGANISMS (Continued)

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[10] Muncy and Oliver (1963).
[11] W.H.O. (1968).
[12] Georghiou (1972).
[13] Macek and McAllister (1970).
[14] U.S.E.P.A. (1975).
[15] Pickering _et_ _al_. (1962).
[16] Eisler (1967).
[17] Brown (1978).
[18] Holden (1973).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	541-892 ppm (8 days)	LC$_{50}$ (oral dose in feed)[1]
Pheasant	101-134 ppm (8 days)	LC$_{50}$ (oral dose in feed)[1]
Bobwhite quail	73-111 ppm (8 days)	LC$_{50}$ (oral dose in feed)[1]
Japanese quail	38-55 ppm (8 days)	LC$_{50}$ (oral dose in feed)[1]
MAMMALS		
Rats	9 mg/kg bw	oral LD$_{50}$[2]
	63 mg/kg bw	dermal LD$_{50}$[2]
Humans	0.001 mg/kg bw	maximum acceptable daily[3] intake (based on highest dietary dose having no effect on ChE activity in humans)
	0.0043 mg/kg/day	acceptable daily intake[4]
	30.0 µg/1	suggested no-adverse effect[4] level from H$_2$O assumption 1[2]
	1.5 µg/1	suggested no-adverse effect[4] level from H$_2$O assumption 2[2]

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments: Methyl parathion is a ChE inhibitor; psychiatric disturbances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961). Studies on rats have indicated that methyl parathion disturbs reproductive physiology (Vettorazzi, 1976).

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[1] Heath *et al*. (1972).

[2] Ware (1978).

[3] Vettorazzi (1976).

[4] NAS (1977).

SECTION 15

PARATHION

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Alkron, Alleron, Bladan, Corothion, E-605, Ethyl Parathion, Ethlon, Folidol E-605, Niran, Orthophos, Panthion, Paramr, Parathene, Parawet, Phoskil, Rhodiatrox, Soprathion, Stathion, Thiophos.

2. Vapor Pressure at 20°C: 3.78×10^{-5} mm Hg (Martin and Worthing, 1977).

3. Solubility in Water at 25°C: 24 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Broad-spectrum, non-systemic contact and stomach insecticide and acaricide with some fumigant action.

2. Primary Crops Used on: Wheat (the use of parathion accounted for 43.1% of the 7.2 million pounds of insecticides used on wheat in 1976); sorghum (use accounted for 26.1% of the 5.4 million pounds of insecticides used in sorghum in 1976); cotton, corn, other grains, alfalfa, soybeans, vegetables, fruits and nuts (Andrilenas, 1974; Eichers, et al., 1978).

3. Rates Commonly Used: In 1971 application rates in crops using parathion averaged 3.72 kg/ha; rates in cotton ranged from 0.84 to 21.02 kg/ha (Carey et al., 1978).

4. Formulations Available: Emulsifiable concentrates, dusts, granules, wettable powders.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Parathion is strongly adsorbed to soil particles. Fifteen years after parathion was applied to a light sandy soil, residues were not found below 20 cm in the soil profile (Voerman and Besemer, 1970). A recent study on adsorption and desorption of several organophosphorus and carbamate insecticides determined the relative adsorption capacities (in order

of most strongly adsorbed to most weakly adsorbed) to be chlorpyrifos > parathion > terbufos > phorate > aldicarb. Sorption of the pesticides reached equilibrium between solution and soil within two hours after application and was positively correlated with organic matter content (Felsot and Dahm, 1979).

2. Persistence and Vapor Losses: Insecticidal activity persists for 3 or more days on exposed plant surfaces (von Rumker et al., 1974). When parathion was applied to a silt loam at the rate of 5.6 kg/ha, 95% of the residues had disappeared after two and one half months. The two major metabolites aminoparathion and p-nitrophenol persisted for 2 and 16 days, respectively, while the minor metabolite, paraoxan, hydrolyzed in 12 months (Lichtenstein and Schulz, 1964). The recent discovery of nonextractable bound residues of parathion in soil (Katan et al., 1976) may bring about a redefinition of parathion's supposed "non-persistence". Parathion is also more persistent when applied at high rates: after applications of 33.6 kg/ha for four consecutive years, residues were found in soil for 16 years after treatment had ceased (Stewart et al., 1971). Spencer (1976) has reviewed the limited data on parathion's vapor losses and has concluded that vaporization may be an important route of dissipation from treated fields. Haque and Freed (1974) have used the best available information to form a vaporization index: according to their estimates, parathion may have vapor losses amounting to 3.5 to 6.5 kg/ha/year or more from a loam soil at 25°C under an annual rainfall of 150 cm. Parathion residues have been detected in air samples taken over Florida (Stanley et al., 1971) and were found in samples of air taken from inside and outside farmers' and pesticide formulators' homes (Tessari and Spencer, 1971).

3. Runoff Losses: In the Bradfield Marsh in Ontario, where parathion may be applied as many as 19 times in a single season for the control of onion maggot adult control, runoff water in ditches draining the black soils contained parathion residues in every sample taken from April to October of 1972; maximum concentrations of 50 ppt or more were observed in April, early July and late October (Harris and Miles, 1974).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: Parathion does not hydrolyze as rapidly as other organophosphates but undergoes microbial degradation in both anaerobic and aerobic aquatic environments (Graetz et al., 1970). Yu and Sanborn (1975) estimated parathion's half-life in water to be 15 to 16 days. When parathion was added to lake water and held in the dark, all but 0.2% of the original material had degraded in one year (Yasuno et al., 1965); however, when parathion was applied to ponds at 1.12 kg/ha, initial concentrations of 450 ppb declined to 3 ppb in two weeks (Mulla et al., 1966). If hydrolysis is the major mode of degradation, the prolonged persistence of parathion

residues will increase toxic hazards to aquatic flora and fauna; the hydrolysis half-life at 20°C and pH 7.4 is 108 days for parathion and 144 days for parathion's more toxic metabolite paraoxon (Faust and Gomaa, 1972). Chemical hydrolysis in alkaline water produces diethylphosphorothioic acid and p-nitrophenol (Paris and Lewis, 1973). When exposed to UV light, parathion oxidizes to several oxidation and degradation products among which is paraoxon, a powerful cholinesterase inhibitor (Frawley et al., 1958).

2. Persistence in Submerged Sediment: When parathion was applied to ponds at 1.12 kg/ha and initial concentrations of 450 ppb in the water, average concentrations in the hydrosoil were 30 ppb three weeks after application; when .11 kg/ha were applied, residues were not found in the hydrosoil 4 days after the application took place (Mulla et al., 1966). Sediments from a eutrophic alkaline (pH 7.2) lake degraded parathion by 28% to 39% in 54 days (averages at 0.74% of the material per day) whereas sediment from a oligotrophic acid (pH 4.7) lake degraded only 26% of the material in 92 days (averages at .28% of the material per day). The primary degradation product was aminoparathion (Graetz et al., 1970).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Chlorella sp.	----	unaffected[1]
Chlorella pyrenoidosa	----	inhibition of photosynthesis[2] and growth increased with decreasing cell concentration; treatment each day for week more toxic than a single treatment at time of inoculation
Anactyis nidulans (blue green)	1 ppm (7 days)	concentrated residues[3] 50 x's
Scenedesmus obliquus (green)	1 ppm (7 days)	concentrated residues[3] 72 x's
Chlamydomonas sp.	----	unaffected[1]
Gonium pectorale	----	could not metabolize[4] parathion in culture
Euglena gracilis	0.01 to 1.2 ppm	generally non-inhibitory[4] to long term growth
Euglena gracilis	10 ppm	cells at different densities[4] killed after 1 and 2 hrs

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Euglena gracilis	1 to 100 ppm (24 hr)	growth not affected[5]
Euglena gracilis	1 to 100 ppm (after 7 days)	growth stimulated[5]
Euglena gracilis (flagellate)	1 ppm (7 days)	concentrated residues[3] 62 x's
Paramecium bursuria (ciliate)	1 ppm (7 days)	concentrated residues[3] 94 x's
Oedogonium cardiacum	----- (33 days)	concentrated residues[6] 144 x's
Anabaena (blue-green algae responsible for intoxicating and killing livestock and wildlife on farm ponds)	3 successive applications of 3 ppb	heavy blooms resulted[7] because of reductions in *Daphnia*, *Cyclops* and *Diaptomas* populations
CONSUMERS		
Crustaceans: cladocerans - *Daphnia pulex*	0.60 ppb (48 hr, 15.6°C)	EC_{50}[8]
Daphnia magna	0.8 ppb (48-50 hr, 68°F)	EC_{50}[8]
Daphnia carinata	0.5 ppb (64 hr, 78°F)	TL_m[9]
Simocephalus serrulatus	0.37 ppb (48 hr, 15.6°C)	EC_{50}[8]
Daphnia	0.5 ppb (7 days)	no bioaccumulation[10]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
BENTHIC INVERTEBRATES		
Oligochaetes: *Tubifex tubifex*	2 ppm (72 hr)	maximum concentration worms could tolerate without mortality[11]
Crustaceans: amphipods - *Gammarus lacustris*	12 ppb (24 hr, 21^{o}C)	LC_{50}[12]
	6 ppb (48 hr, 21^{o}C)	LC_{50}[12]
	3.5 ppb (96 hr, 21^{o}C)	LC_{50}[12]
: freshwater shrimp - *Palaemonetes radiakensis*	6.6-11.8 ppb (24 hr, 21-27^{o}C)	LC_{50}[13]
Insecta: stonefly naiads - *Pteronarcella badia*	8.0 ppb (24 hr, 15.5^{o}C)	LC_{50}[14]
	5.6 ppb (48 hr, 15.5^{o}C)	LC_{50}[14]
	4.2 ppb (96 hr, 15.5^{o}C)	LC_{50}[14]
Claassenia sabulosa	8.8 ppb (24 hr, 15.5^{o}C)	LC_{50}[14]
	3.5 ppb (48 hr, 15.5^{o}C)	LC_{50}[14]
	1.5 ppb (96 hr, 15.5^{o}C)	LC_{50}[14]
Pteronarcys californica	28 ppb (24 hr, 15.5^{o}C)	LC_{50}[14]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Insecta : stonefly naiads - *Pteronarcys californica*	11 ppb (48 hr, 15.5°C)	LC_{50}[14]
	5.4 ppb (96 hr, 15.5°C)	LC_{50}[14]
	36 ppb (5 day, 12.8°C)	TL_m[15]
	2.2 ppb (30 day, 12.8°C)	TL_m[15]
Acroneuria pacifica	0.93 ppb (5 day, 12.8°C)	TL_m[15]
	0.44 ppb (30 day, 12.8°C)	TL_m[15]
: mosquito larvae - *Culex fatigans*	3.2 ppb (24 hr)	LC_{50}[16]
Anopheles albimanus	3.1 ppb (24 hr)	LC_{50}[17]
Invertebrates (not identified)	----	did not bioaccumulate[6]
:caddisflies - *Arctopsyche grandis*	7 ppb (96 hr, 51-54°C)	LC_{50}[18]
Hydropsyche californica	0.43 ppb (96 hr, 51-54°C)	LC_{50}[18]
: mayflies - *Ephemerella grandis*	3 ppb (96 hr, 48-50°C)	LC_{50}[18]
FISH		
Rainbow trout	2 ppb (48 hr)	LC_{50}[12]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH (Continued)		
Goldfish	2.7 ppm (96 hr)	TL_m[19]
Goldfish	0.001 ppm	significant reductions in[20] brain cholinesterase; no recovery of normal cholinesterase levels 1 mo after fish transferred to clean water
Fathead minnow	1.4-2.7 ppm (96 hr)	TL_m[21]
Carp	1 ppm (96 hr)	LC_{100}[22]
Bluegill sunfish	0.047 ppm (48 hr)	LC_{50}[23]
Bluegill sunfish	0.1 ppm (96 hr)	TL_m[19]
Guppies	0.05 ppm (96 hr)	TL_m[19]
Golden shiners	sublethal concentrations (2 days)	50-60% reduction in lymphocytes, heterophils and total leucocytes; 20% reduction in blood haematocrit[24]
Mosquito fish	0.19 ppm (36 hr)	50% mortality[25]
Mosquito fish	0.02 ppm (4 hr)	concentrated residue to[26] 15 ppm in tissues

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH (Continued)		
Mosquito fish	---- (3 days)	ratio residue in fish to residue in water = 335:1[6]
Fish	sublethal concentrations	behavioral responses[27]
Mummichog	sublethal concentrations	retardation of fin regeneration[28]
Mummichog (minnow)	0.12 ppm (2 days)	concentrated residues 80 fold in tissue[29]
Fish	-----	half-life of toxic residues in fish tissue less than one week[30]
AMPHIBIANS		
Western Chorus frog (tadpoles)	1.6 ppm (24 hr, 15.5°C)	LC_{50}[31]

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[1] Loosanoff *et al*. (1957).

[2] Cole and Platt (1970).

[3] Gregory *et al*. (1969).

[4] Moore (1970).

[5] Poorman (1973).

[6] Sanborn (1974).

[7] Cook and Connors (1963).

[8] Sanders and Cope (1966).

[9] Matida and Kawasaki (1958).

[10] Priester (1965).

E. IMPACT ON AQUATIC ORGANISMS (Continued)

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11 Naqvi and Ferguson (1968).
12 Sanders (1969).
13 Nagvi and Ferguson (1970).
14 Sanders and Cope (1968).
15 Jensen and Gaufin (1966).
16 W.H.O. (1968).
17 Georghiou (1972).
18 Gaufin et al. (1965).
19 Pickering et al. (1962).
20 Weiss (1959).
21 Henderson et al. (1959).
22 Lahav and Sarig (1969).
23 FWPCA (1968).
24 Butler et al. (1969).
25 Lewallen and Wilder (1962).
26 Mulla et al. (1966).
27 Kleerekoper (1974).
28 Weis and Weis (1975).
29 Miller et al. (1966)
30 Macek (1970).
31 Sanders (1970).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	250-275 ppm (5 days treated feed followed by 3 days clean feed)	LC$_{50}$[1]
Pheasants	350-380 ppm (" " " ")	LC$_{50}$[1]
Bobwhite quail	180-200 ppm (" " " ")	LC$_{50}$[1]
Coturnix quail	40-50 ppm (" " " ")	LC$_{50}$[1]
MAMMALS		
Rats	3 mg/kg bw	oral LD$_{50}$[2]
	4 mg/kg bw	dermal LD$_{50}$[2]
Humans	0.005 mg/kg bw	maximum acceptable daily intake[3]
	0.0043 mg/kg/day	acceptable daily intake[4]
	30.0 µg/l	suggested no-adverse[4] effect level from H_2O - assumption 1
	1.5 µg/l	suggested no-adverse effect[4] level from H_2O - assumption 2[2]

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

Other Comments:	Parathion is a ChE inhibitor: psychiatric disturbances have been reported in workers who were repeatedly exposed to organophosphorus insecticides over periods of 1-1/2 to 10 years (Gershon and Shaw, 1961).

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[1] Heath et al. (1970).

[2] Ware (1978).

[3] Vettorazzi (1976).

[4] NAS (1977).

SECTION 16

PHORATE

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Thimet, Timet

2. Vapor Pressure at 20°C: 8.4×10^{-4} mm Hg (Sanborn et al., 1977).

3. Solubility in Water at 26°C: 19 ppm (Freed, 1976).

B. USE

1. Type: Systemic and contact insecticide and acaricide.

2. Primary Crops Used on: Corn (the use of phorate accounted for 18.1% of the 32.0 million pounds of insecticides used in corn in 1976); cotton, sorghum, other grains, peanuts, alfalfa, soybeans, Irish potatoes (Andrilenas, 1974; Eichers, et al., 1978).

3. Rates Commonly Used: In 1971 application rates in crops using phorate averaged at 1.91 kg/ha; rates in field corn ranged from 0.19 to 16.81 kg/ha (Carey et al., 1978).

4. Formulation Available: Emulsifiable concentrates, granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Phorate is strongly adsorbed to soil particles. Studies in 17.8 cm soil columns have indicated that phorate is only slightly mobile within soil (Harris, 1969). A recent study on adsorption and desorption of several organophosphorus and carbamate insecticides determined the relative adsorption capacities (in order of most strongly adsorbed to most weakly adsorbed) to be chlorpyrifos > parathion > terbufos > phorate > aldicarb. Sorption of the pesticides reached equilibrium between solution and soil within two hours after application and was positively correlated with organic matter content (Felsot and Dahm, 1979).

2. Persistence and Vapor Losses: One hour after application to

the soil, more than 50% of the phorate had been converted to the insecticidal phorate sulfoxide; phorate sulfoxide is then converted to phorate sulfone (Ahmed and Casida, 1958) which persists for up to one year (Harris et al., 1972). Fifty percent of the phorate applied to sandy soil and peaty loam degraded within 68 days and 35 days, respectively (Way and Scopes, 1968; Suett, 1971); in a Coachella fine sand, residues persisted for more than 2 months but disappeared less than 6 months after application (Mulla, 1964; Mulla et al., 1961). Burns (1971) observed a rapid disappearance of phorate from a sandy soil (41% loss in first 3 days after application) and largely attributed it to volatilization losses; Spencer (1976) reviewed the limited data on phorate's vapor pressure and concluded that there is a strong potential for high volatility in field conditions.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: When the rate of degradation by chemical hydrolysis was tested in a buffer solution (20:80) having a pH of 6.9, the half-life of phorate was 450 hours (~ 19 days) (Faust and Gomaa, 1972).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Chlorella pyrenoidosa	1000 ppm	metabolized phorate[1]
Marine phytoplankton	---	growth much more inhibited[2] by organochlorine insecticides than by organophosphorus insecticides (phorate not tested)
estaurine phytoplankton	1000 ppb (4 hr)	average inhibition of 75.3%[3] for 12 organochlorine insecticides tested; only 5 out of 13 organophosphorus insecticides caused reductions in excess of 10% (average inhibition = 25.5%) phorate not tested
CONSUMERS		
Crustaceans: cladocerans - *Daphnia pulex* (zooplankton)	148 ppb (48 hr)	average EC_{50} for 12 organochlorines tested[4]
	1.7 ppb (48 hr)	average EC_{50} for 10 organophosphorus compounds tested (phorate not tested)[4]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
BENTHIC INVERTEBRATES		
Crustaceans: amphipod - *Gammarus lacustris*	24 ppb (24 hr, 21°C)	LC_{50}[5]
	14 ppb (48 hr, 21°C)	LC_{50}[5]
	9.0 ppb (96 hr, 21°C)	LC_{50}[5]
FISH		
Bluegill sunfish	0.0055 ppm (48 hr)	LC_{50}[6]
Harlequin fish	< 1.0 ppm (24 hr)	LC_{50}[7]
AMPHIBIANS		
Bullfrog	95 mg/kg (24 hr)	LD_{50}[8]

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[1] Ahmed and Casida (1958).

[2] Ukeles (1962).

[3] Butler (1963) in Hurlbert (1975).

[4] Sanders and Cope (1966).

[5] Sanders (1969).

[6] FWPCA (1960).

[7] Alabaster (1969).

[8] MPCA (1979).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallards	225-275 ppm (5 days treated feed followed by 3 days clean feed)	LC_{50}[1]
Pheasants	400-800 ppm (" " " ")	LC_{50}[1]
Bobwhite quail	370-400 ppm (" " " ")	LC_{50}[1]
MAMMALS		
Rats	1 mg/kg bw	oral LD_{50}[2]
	2 mg/kg bw	dermal LD_{50}[2]
Humans	0.0001 mg/kg/day	acceptable daily[3] intake
	0.7 µg/1	suggested no-adverse[3] effect level from H_2O - assumption 1
	0.035 µg/1	suggested no-adverse[3] effect level from H_2O - assumption 2

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[1] Heath _et_ _al_. (1970a). [2] Ware (1978). [3] NAS (1977).

SECTION 17

TERBUFOS

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Counter

2. Vapor Pressure at 25°C: 2.6×10^{-4} mm Hg (Martin and Worthing, 1977).

3. Solubility in Water at Room Temperature: 10 to 15 ppm (Martin and Worthing, 1977).

B. USE

1. Type: Insecticide particularly effective against soil insects.

2. Primary Crops Used on: Corn (Eichers *et al.*, 1978).

3. Formulations Available: Granules.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: A recent study on the adsorption and desorption of several organophosphorus and carbamate insecticides determined the relative adsorption capacities (in order of most strongly adsorbed to most weakly adsorbed) to be chlorpyrifos > parathion > terbufos > phorate > aldicarb. Sorption of the pesticides reached equilibrium between solution and soil within two hours after application and was positively correlated with organic matter content (Felsot and Dahm, 1979). Given the results of this study, leaching would not be expected to move terbufos more than 20 cm through the soil.

2. Persistence: When terbufos was added to soil, the original material oxidized rapidly to its sulfoxide and had a half-life of only 4 to 5 days. The sulfoxide reached maximum concentrations 2 weeks after the experiment began and in turn oxidized to terbufos sulfone. Since the metabolites demonstrate insecticidal toxicity equal to that of terbufos, the researchers suggested a half-life of 6 weeks for terbufos and its metabolites in soil (LaVeglia and Dahm, 1977).

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence: No information was available on the degradation of terbufos in water and submerged sediments (see FONOFOS for general information on the persistence of organophosphates in aquatic systems).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
Marine phytoplankton	---	growth much more inhibited[1] by organochlorine insecticides than by organophosphorus insecticides (terbufos not tested)
Estaurine phytoplankton communities	1000 ppb (4 hr)	average inhibition of 75.3%[2] for 12 organochlorine insecticides tested; only 5 of 13 organophosphorus insecticides caused reductions in excess of 10% (average inhibition = 25.5%) terbufos not tested
CONSUMERS		
Crustaceans: cladocerans Daphnia pulex (zooplankton)	148 ppb (48 hr, 15.6°C)	average EC_{50} for 12 organochlorines tested[3]
	1.7 ppb (48 hr, 15.6°C)	average EC_{50} for 10 organophosphorus compounds tested[3] (terbufos not tested)

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[1] Ukeles (1962).

[2] Butler (1963) in Hurlbert (1975).

[3] Sanders and Cope (1966).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin	Results
MAMMALS		
Rats	4 mg/kg bw	oral LD_{50}[1]
	1 mg/kg bw	dermal LD_{50}[1]

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[1] Ware (1978).

SECTION 18

TOXAPHENE

A. NOMENCLATURE, CHEMICAL AND PHYSICAL PROPERTIES

1. Product Names: Camphechlor, Alltox, Phenacide, Phenatox, Strobane-T, Toxakil.

2. Vapor Pressure at 25°C: 0.2 to 0.4 mm Hg (Finlayson and MacCarthy, 1973).

3. Solubility in Water at Room Temperature: 3 ppm (Martin and Worthing, 1977).

B. USE:

1. Type: Non-systemic contact and stomach insecticide with some acaricidal action.

2. Primary Crops Used on: Cotton (the use of toxaphene accounted for 41% of the 64.1 million pounds of insecticides used in cotton in 1974); soybeans (the use accounted for 27.9% of 7.9 million pounds of insecticides used in soybeans in 1976); sorghum (use accounted for 21.7% of 4.6 million pounds of insecticides used in sorghum in 1976); peanuts (use accounted for 16.7% of 2.4 million pounds of insecticides used in peanuts in 1976); wheat (Andrilenas, 1974; Eichers *et al*., 1978).

3. Rates Commonly Used: In 1971 application rates in crops using toxaphene averaged 7.84 kg/ha; rates in cotton ranged from 0.10 to 40.35 kg/ha (Carey *et al*., 1978).

4. Formulations Available: Emulsifiable concentrates, wettable powders, dust, granular.

C. BEHAVIOR IN TREATED FIELDS

1. Adsorption and Leaching Characteristics: Toxaphene is very strongly adsorbed to soil particles. Ten years after application, 95% of the residues remaining in a Houston black clay were found in the top 30 cm of the soil profile (Swoboda *et al*.,1971). When 100 kg/ha were applied to study "sterilant concentrations",

toxaphene residues leached through approximately 300 cm of soil and entered and contaminated groundwater for the entire year of observation (LaFleur et al., 1973).

2. Persistence and Vapor Losses: Vaporization plays a very major role in the disappearance of toxaphene from soil surfaces and treated foliage. Studies on cotton grown in the San Joaquin Valley have shown that the residues remaining on leaves 50 days after treatment (135 ppm) "showed a regular trend toward greater loss of components of higher volatility when compared with the 0-day sample (661 ppm) (Seiber et al., 1979). Nash et al. (1977) found that twenty-four percent of the applied toxaphene volatilized from soil and cotton plant surfaces in a model ecosystem. The authors suggested that volatilization losses in the field might be larger because cotton plants are more widely spaced and thus allow more of the volatilization losses from the soil to escape to the atmosphere. Swoboda et al (1971) observed the rapid disappearance of toxaphene from a heavy clay soil and attributed it to large volatilization losses encouraged by daily soil temperatures of 60°C. Haque and Freed (1974) used available information to quantify annual vaporization losses of pesticides from soil and estimated that 7-14 kg/ha of toxaphene would vaporize from a loam soil at 25°C. Toxaphene has been detected in air samples taken over the Southern U.S. (Stanley et al., 1971; Arthur, 1976) and Bermuda (Bidleman and Olney, 1975); atmospheric residue levels over the southern states were as high as 2500 ng/m^3 while mean residue levels in Bermuda were 0.63 ng/m^3. Residue levels of 280, 170, 44, 86 and 220 ppt in five out of eight rainwater samples collected in Maryland indicate that some of the air-borne toxaphene is redeposited on the earth's surface (Munson, 1976). Toxaphene residues which escape volatilization will persist for prolonged periods in the soil; Nash and Harris (1973) studied the persistence of toxaphene in a Congaree sandy loam and found 49% of the material remaining 16 years after application.

3. Runoff Losses: When eight different plots of cotton grown on loamy sand and sandy loam soils (slopes of 2% and 4%, respectively) were treated with 26.9 kg/ha of toxaphene, 0.078 to 0.72% of the pesticide was transported away from the field during the 3 to 6 months following treatment; approximately 75% of the toxaphene leaving the field in runoff was associated with the sediment phase with the remainder of the residues being transported in the dissolved phase (Bradley et al., 1972). While these losses appear to be small when seen as a percentage of the material applied, they take on greater significance when it is observed that 0.078 to 0.72 percent of the 26.9 kg/ha applied results in losses of 21 to 200 gm/ha of toxaphene. Given large tracts of cotton acreage, these losses could result in serious contamination problems in surface waters located in

cotton growing areas. Bradley et al. (1972) did find that significant concentrations of toxaphene appeared in a 0.2 hectare pond located in the experimental watershed. Concentrations increased from levels of less than 1 ppb before the cotton was treated to 65 ppb at midseason and equaled or exceeded the ninety-six hour median tolerance for bluegill on all but one occasion during the growing season. The authors attributed this toxaphene pollution to runoff but did not study possible residue inputs from drift losses and contaminated rainfall.

D. BEHAVIOR IN AQUATIC SYSTEMS

1. Persistence in Water: The task of determining toxaphene's persistence in aquatic systems is difficult because of the insecticide's chemical complexity (although the technical material has been shown to contain nearly 200 polychlorinated camphenes, its chemical composition remains largely undetermined - Holmstead et al., 1974) and reversible sorption to aquatic flora and fauna (Pollack and Kilgore, 1978). High evaporation rates (MacKay and Wolkoff, 1973) and sorption onto suspended sediments (Hughes and Lee, 1968; Veith and Lee, 1971; Terriere et al., 1966; Stringer and McMynn, 1958) have both been identified as mechanisms for the removal of toxaphene from solution. Concentrations of toxaphene in a shallow eutrophic lake declined by 99% one year after application, whereas concentrations in a deep oligotrophic lake were still toxic to fish 5 years later (Terriere et al., 1966). Initial treatment concentrations of 50 ppb declined to 1 ppb one month after application in a shallow New Mexico Lake; however, concentrations did not further decline for the next 9 months (Kallman et al., 1962).

2. Persistence in Submerged Sediment: When a shallow New Mexico Lake was treated at 50 ppb, concentrations of toxaphene in the lake sediment reached levels of 150 ppb (Kallman et al., 1962). When eight Wisconsin lakes were treated at 100 ppb, residue concentrations in submerged sediments ranged from 0.2 to 1 ppm for 3 to 9 years after treatment (Johnson et al., 1966). Williams and Bidleman (1978) studied the degradation of toxaphene in an anaerobic salt marsh and found that residues were quickly degraded in sterile and non-sterile sediment to compounds having gas chromatograph retention times shorter than those of standard toxaphene components. Lee et al. (1977) found "weathered" toxaphene components to be less toxic to bluegills and concluded that some of the more toxic components had indeed degraded.

3. Persistence in Aquatic Vegetation: When a shallow New Mexico Lake was treated at 50 ppb, concentrations in aquatic plants

peaked at 18 ppm one week after application and remained above 2 ppm for 3 years (Kallman et al., 1962).

E. IMPACT ON AQUATIC ORGANISMS

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
DECOMPOSERS AND PRIMARY PRODUCERS		
estaurine phytoplankton	1000 ppb (4 hrs)	productivity reduced by[1] 91%
freshwater algae	0.001 and 0.01 ppm	growth not affected[2]
freshwater algae	0.1 and 1 ppm	growth inhibited[2]
algae	----	concentrated residues[3] 6902 x's levels found in water
freshwater phytoplankton	0.2 ppm	concentrated residues in[4] water to levels of 73 ppm
Microcystis aeruginosa	2 ppm	toxic[5]
Cylindrospermum licheniforme	2 ppm	partially toxic[5]
Scenedesmus obliquus	2 ppm	generally nontoxic[5]
Chlorella variegata	2 ppm	generally nontoxic[5]
Nitzchia palea	2 ppm	generally nontoxic[5]
Scenedesmus quadricauda	0.1 and 1 ppm	reduction in cell numbers,[6] carbon assimilation and biomass

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
several marine phytoplanktors	0.15 ppm	growth prevented[7]
Monochrysis lutheri	0.1 ppm	growth eliminated[7]
CONSUMERS		
Entomostraca: sp.) important *Rotifera*: sp.) fish *Protozoa*: sp.) foods	0.1 ppm	inhibited[8]
Crustaceans: cladocerans - *Daphnia pulex*	15 ppb (48 hr, 15.6°C)	EC_{50}[9]
Simocephalus serrulatus	19 ppb (48 hr, 15.6°C)	EC_{50}[9]
Daphnia	-----	concentrated to levels toxic to fish[10]
BENTHIC INVERTEBRATES		
Oligochaetes: *Tubifex tubifex*	6 ppm (72 hr)	maximum concentrations worms could tolerate without mortality[11]
Crustaceans: amphipods - *Gammarus lacustris*	180 ppb (24 hr, 21°C)	LC_{50}[12]
	70 ppb (48 hr, 21°C)	LC_{50}[12]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Crustaceans: amphipods (Cont'd)		
Gammarus lacustris	26 ppb (96 hr, 21°C)	LC_{50}[12]
oysters	1 ppm each of DDT, toxaphene, parathion	gained less weight and more subject to mycelial fungal infections than control oysters; single pesticides had no effect[13]
Insecta: stonefly naiads -		
Pteronarcella badia	9.2 ppb (24 hr, 15.5°C)	LC_{50}[14]
	5.6 ppb (48 hr, 15.5°C)	LC_{50}[14]
	3.0 ppb (96 hr, 15.5°C)	LC_{50}[14]
Claassenia sabulosa	6.0 ppb (24 hr, 15.5°C)	LC_{50}[14]
	3.2 ppb (48 hr, 15.5°C)	LC_{50}[14]
	1.3 ppb (96 hr, 15.5°C)	LC_{50}[14]
Pteronarcys californica	18 ppb (24 hr, 15.5°C)	LC_{50}[14]
	7.0 ppb (48 hr, 15.5°C)	LC_{50}[14]
	2.3 ppb (96 hr, 15.5°C)	LC_{50}[14]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
Invertebrates (not identified)	2 ppb	in deep oligotrophic lake[15] concentrated to maximum of 5 ppm; in shallow eutrophic lake concentrated to 1500 x's level in water
FISH		
Rainbow trout	50 ppb (24 hr)	LC$_{50}$[16]
	2.8 ppb (48 hr)	LC$_{50}$[17]
	4 ppb (48 hr, 24^{o}C)	LC$_{50}$[18]
	11 ppb (96 hr)	TL$_{m}$[19]
Rainbow trout	----	concentrated toxic residues[15] 18829 fold in tissues
Brown trout	3 ppb (96 hr)	TL$_{m}$[19]
Brook trout	0.050 ppb	fry developed weakness in[20] backbone (due to collagen deficiency) and slight decrease in growth rate
Coho salmon	8 ppb (96 hr)	TL$_{m}$[19]
Yellow perch	12 ppb (96 hr)	TL$_{m}$[19]
Red ear sunfish	13 ppb (96 hr)	TL$_{m}$[19]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH (Continued)		
Largemouth Bass	2 ppb (96 hr)	TL_m[19]
Channel catfish	13 ppb (96 hr)	TL_m[19]
Goldfish	14 ppb (96 hr)	TL_m[19]
Goldfish	sublethal concentrations	caused fish to become hypersensitive[21] to external stimuli (this would possibly render[22] fish more easily caught by predators Hurlbert, 1975)
Fathead minnow	14 ppb (96 hr)	TL_m[19]
Fathead minnow	0.050 ppb	fry developed weakness in[20] the backbone (due to collagen deficiency) and slight decrease in growth rate
Carp	4 ppb (96 hr)	TL_m[19]
Bluegill sunfish	9.7 ppb (24 hr, 12.7°C)	TL_m[23]
	6.8 ppb (24 hr, 18.3°C)	TL_m[23]
	6.6 ppb (24 hr, 23.8°C)	TL_m[23]
	4 ppb (48 hr, 24°C)	LC_{50}[18]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

Organisms Tested	Concentration of toxin (exposure time and temperature)	Results
FISH (Continued)		
Bluegill sunfish	18 ppb (96 hr)	TL_m[19]
Black bullhead	7.2 ppb (24 hr)	LC_{50}[24]
	5 ppb (48 hr)	TL_m[19]
Guppies	20 ppb (96 hr)	TL_m[25]
Mosquito fish	concentrations above threshold toxicity	survived but aborted young[26]
Fish	sublethal concentrations	behavioral disturbances[27]
Fish	----	residues in tissues had a[28] half-life of > 6 mos
AMPHIBIANS		
Fowler's toad (tadpoles)	600 ppb (24 hr, 15.5°C)	LC_{50}[29]
Western Chorus frog (tadpole)	1700 ppb (24 hr, 15.5°C)	LC_{50}[29]

E. IMPACT ON AQUATIC ORGANISMS (Continued)

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[1] Butler (1963).
[2] Butler *et al.* (1975b).
[3] Metcalf *et al.* (1971).
[4] Hunt and Keith (1963).
[5] Palmer and Maloney (1955).
[6] Stadnyk *et al.* (1971).
[7] Ukeles (1962).
[8] Hoffman and Olive (1961).
[9] Sanders and Cope (1966).
[10] Schoettger and Olive (1961).
[11] Naqvi and Ferguson (1968).
[12] Sanders (1969).
[13] Lowe *et al.* (1970).
[14] Sanders and Cope (1968).
[15] Terriere *et al.* (1966).
[16] Mayhew (1955).
[17] FWPCA (1968).
[18] Cope (1966).
[19] Macek and McAllister (1970).
[20] Mehrle and Mayer (1977).
[21] Warner *et al.* (1966).
[22] Stickel (1967).
[23] Macek *et al.* (1969).
[24] USDI (1964).
[25] Henderson *et al.* (1959).
[26] Boyd (1964).
[27] Holden (1973).
[28] Macek (1970).
[29] Sanders (1970).

F. IMPACT ON TERRESTRIAL ORGANISMS

Organisms Tested	Concentration of toxin (exposure time)	Results
BIRDS		
Mallard ducklings	563 ppm (5 days treated feed followed by 3 days clean feed)	LC$_{50}$[1]
Pheasants	500-550 ppm (" " " ")	LC$_{50}$[2]
Bobwhite quail chicks	834 ppm (" " " ")	LC$_{50}$[1]
Coturnix quail	600-650 ppm (" " " ")	LC$_{50}$[2]
MAMMALS		
Rats	40 mg/kg bw	oral LD$_{50}$[3]
	600 mg/kg bw	dermal LD$_{50}$[3]
Humans	0.00125 mg/kg/day	acceptable daily intake[4]
	8.75 µg/l	suggested no-adverse effect[4] level from H_2O - assumption 1[2]
	0.44 µg/l	suggested no-adverse effect[4] level from H_2O - assumption 2[2]

Other Comments: Although toxaphene is stored in the fat tissues of animals the high degree of bioaccumulation seen with other organochlorine insecticides does not occur; toxaphene residues are also more rapidly eliminated when exposure is discontinued (Vettorazzi, 1975). Toxaphene has been RPARed because of possible carcinogenic effects.

F. IMPACT ON TERRESTRIAL ORGANISMS (Continued)

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[1] Heath and Stickel (1965).

[2] Heath *et al*. (1970).

[3] Ware (1978).

[4] NAS (1977).

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APPENDIX F

ECONOMIC PERSPECTIVE AND EVALUATION METHODS FOR AGRICULTURAL NONPOINT SOURCE WATER QUALITY MANAGEMENT

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SECTION 1

AN ECONOMIC PERSPECTIVE OF NONPOINT POLLUTION CONTROL

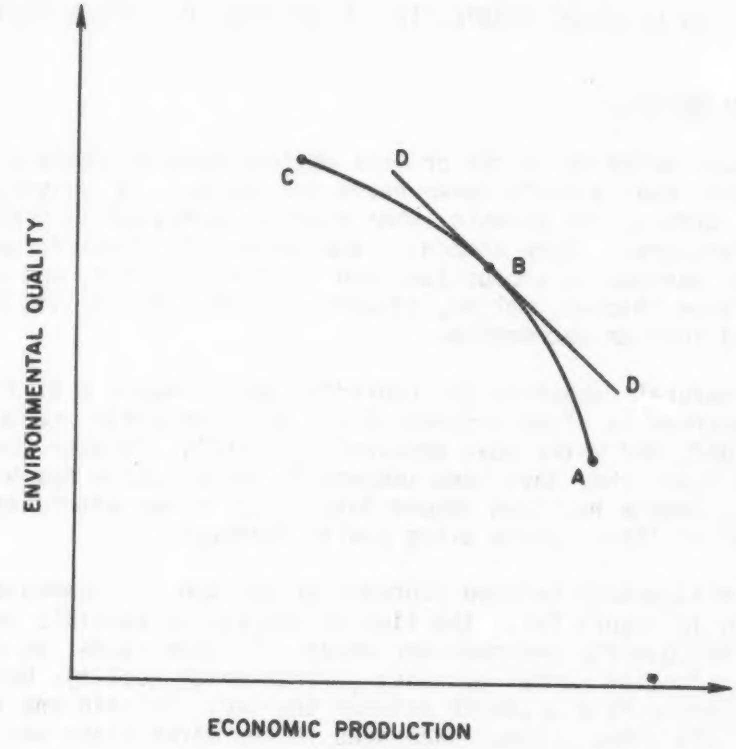
THE PROBLEM DEFINED

Economic activity is the process whereby natural resources are converted into products that satisfy human needs and wants. The conversion may be relatively direct, for example, when wind is harnessed to pump water for an isolated farmstead. More commonly, the conversion involves many steps, as in the case of automobile production; ore is mined, melted, and cast into pigs, which are then shipped, melted, stamped, rolled, shaped, and eventually transformed into an automobile.

When natural resources are converted via economic activity, the change in the resources is often irreversible. Until recently, resources such as air, sunlight, and water have appeared plentiful. Because they have been treated as free, they have been subject to abuse; smoke has been emitted into 'free' air, sewage has been dumped into 'free' river water, and cans have been thrown on 'free' grass along public roadways.

The relationship between economic growth and environmental quality is generalized in Figure F-1. The line AC represents possible combinations of environmental quality and consumer goods. In some cases, we might actually increase production while improving environmental quality. However, more typically, there is a tradeoff between the two. To gain one requires giving up some of the other. Goods exchanged in the marketplace are given a value. The value placed on environmental quality, however, may not always be clear. To the extent that the relative values placed on consumer goods and environmental quality can be compared, such a comparison allows us to determine the slope of the maximum revenue (total utility) line DD as an indicator of the relative preference between the two alternatives. It can be shown, for example, that complete abatement of pollution from irrigation return flows would be very costly, and would probably include a significant reduction in food production. The public might prefer to operate at point B, where we have a moderate supply of goods and a tolerable environment. Those with a preference for a more pristine environment, however, might prefer to operate at point C, and the producer might prefer to operate at point A, where production is maximized, but at a greater cost to the environment. **A major problem in arriving at a socially desirable mix of commercial goods and environmental quality is that the preference for these alternatives are indicated in different ways. Market prices serve to indicate our desire for consumer goods, but there is generally no such convenient method for measuring preferences for an improved environment.**

Figure F-1. Generalized relationship between economic production and environmental quality.



PROPERTY RIGHTS

Property rights are the rules of resource ownership and use. 'Resources' include minerals, soil, air, water, etc., commonly referred to as 'natural' resources, and in addition, such items as automobiles, furniture, and wages. In this context, resources refer to natural resources only.

Private Property

Private property rights conferred upon the owner of an object provide him/her with the privilege of exclusive use and the right to transfer its use to anyone else whenever that becomes advantageous. Society may impose rules that restrict the use of the item, but the individual who holds title to the item is the only one who can use the item within the bounds of the law. Private land is owned by individuals or groups, but restrictions on land use may be imposed through zoning or building codes. If all activities of people were carried out exclusively through the use of private property, the market would measure the positive value or utility, and the negative value, or disutility, derived by people from the use of a good. A great deal of disutility or loss of value is created by the use of private property items such as automobiles which emit exhaust fumes or by residues from fertilizers which are carried onto other properties.

Common Property

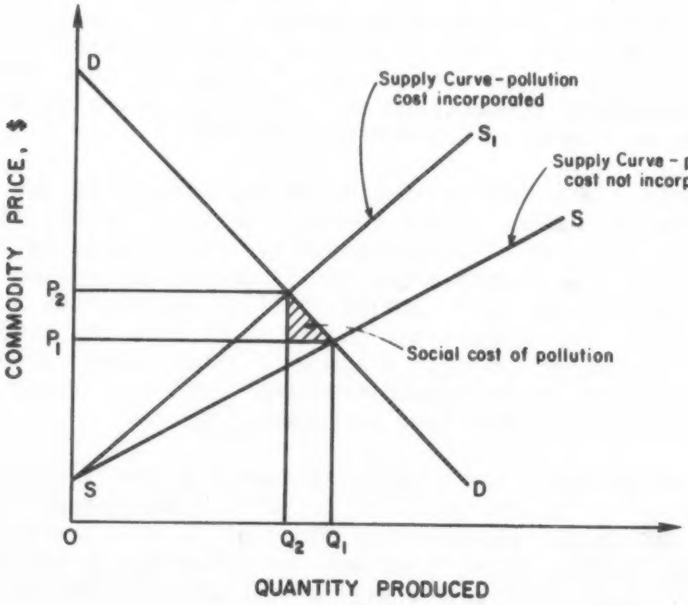
Our markets are well equipped to guide resources into productive uses and to distribute economic rewards among members of the community as long as we are dealing only with the class of goods or resources known as private property. There is, however, a large class of resources that are not susceptible to restrictive property rules. These are known as common property resources or simply as "community property".

Common property rights are not possessed exclusively by one individual, and thus are nontransferrable. Truly common rights are vested equally in each citizen, and allocation of common property resources among individiuals becomes problematic. Some common property is subject to limited individual choice, such as the sailing, water skiing, or fishing services available from a publicly owned lake; individuals may choose to utilize the wind for sailing or the water for fishing or skiing. The use of other common property is intensive, and characterized by competition and conflict. Water used for irrigation is an example of this type of common property.

There is no marketplace where users of common property resources can interact and negotiate. If one person's use of a common property resource serves to damage the incentive or reduce the profits of a second person, the second person has absorbed a cost that will be reflected in the value of his other resources. Pollution commonly yields this effect. Mutual benefits can occur, on the other hand; one farmer's drain system, for example, may lower the water table on his neighbor's land.

Problems arise because we cannot assign property rights to resources such as water and air. These public resources become the sinks for many of the discharges or unwanted by-products of production processes in our economy. Some of the costs of producing a particular good are imposed on people outside the market regime of those actually producing or consuming the goods. This phenomenon is illustrated in Figure F-2. The curve SS indicates a supply of consumer goods being provided in a market economy. A quantity Q_1 can be provided at a price P_1. The demand curve for these consumer goods is indicated by curve DD. **The production of goods, such as the food which comes from agriculture, can result in environmental degradation with costs falling upon others outside of agriculture.** There is a social cost which the producers of food and pollution do not incorporate in their decision-making. If the costs of environmental degradation were assigned to the polluter or to the goods causing such pollution, it would raise the costs of those consumer goods to the level of curve SS_1. After recognition of these additional costs, there would result a new equilibrium with fewer consumer goods produced at higher costs; the quantity produced would be reduced to Q_2 and the price raised to P_2.

Figure F-2. Adjustment in output which might result from an incorporation of environmental costs.



Such **"internalization" of pollution costs via the marketplace would solve many of our environmental problems, but this is usually impractical. Public intervention into the private market is the most common means of internalizing pollution costs.**

ECONOMIC CONCEPTS

Market prices generally serve to guide resources into their most productive uses. The prices of production factors and goods are assumed to represent the contribution of each to social welfare. If knowledge is perfect, even the level of pollution will not exceed society's desires. Under such circumstances, the homemaker who buys beef in New York is assumed to be paying for the damage caused by odors near the meat packing plant or for damages due to stream pollution near the point of production. Obviously, these conditions do not hold in fact. Pollution costs are not completely absorbed or internalized, and homemakers near the pollution source are not fully compensated.

Externalities

An economist describes the incompleteness of the production system as "externalities". For example, a farmer will strive to maximize profits by combining land, water, fertilizer, labor, and sunshine to produce crops in an efficient way. In the process, he may create externalities such as air pollution (dust or odors) or water pollution (sediment or nutrients) which can harm or reduce the welfare of others.

Opportunity Costs

Externalities generally can not be easily measured. To determine the impacts of externalities, the economist relies heavily on the concept of opportunity cost. Briefly defined, **the opportunity cost of a resource is the value of its best alternative use.** Water used for irrigation may yield a profit of $15 per acre foot. If the same water were used to generate power, it might have a value of $20 per acre foot. This $20 becomes the opportunity cost of water used for agricultural production.

The concept of opportunity costs can be used to assess the impact of pollution that reduces the recreational value of a lake. The value of lost recreation is measured by the costs required to develop alternative means of recreation. Construction and maintenance of swimming pools, and travel to more distant lakes, may all be involved.

The opportunity costs of resource use can be used to measure pollution costs and to help determine whether or not pollution abatement programs should be undertaken. Although the opportunity cost is the key to damage assessment, the distribution of damages among members of society is also useful in rendering opinions about allocating the costs of pollution abatement. **The magnitude of opportunity costs and their distribution among members of society become an index of the pollution costs; they become a standard against which the benefits of pollution abatement can be judged.**

The distribution of opportunity costs is often difficult to determine. When responsibility for damage is widely distributed, for example when return flows from irrigation in the Upper Colorado River cause damage throughout the Southwest desert, enforcing payment for this damage is extremely complicated.

Abatement Costs and Benefits

The ideal criteria for setting pollution abatement standards would be to have a perfect knowledge of the costs and benefits of pollution abatement. Generally, the costs of pollution abatement can be identified because they are determined in the marketplace. The measure of abatement costs used in this report is the decrease in net farm income (uncompensated) for alternative management practices. **There is no standard measure of abatement benefits,** however. Health, recreation, or aesthetic effects are nearly impossible to quantify in a manner that allows them to be compared with other, largely economic costs. Even factors that can be measured in economic terms, such as land values or production costs, are often difficult to quantify as a function of pollution abatement.

Despite the problems of measuring pollution abatement benefits, such measurement should remain a goal. To the extent that this goal is reached, we can be more confident that imposed environmental standards are optimally designed to meet social goals. Since the identification and measurement of benefits will identify those who receive the benefits, a more valid basis for distribution of abatement costs will result.

METHODS OF ABATEMENT

There are three broad classes of solutions to environmental quality problems: (1) market solutions, following the establishment of liability rules to serve as a starting point for negotiations, **(2) systems of per-unit taxes, charges, fines or subsidies** designed to alter pollution levels by influencing production methods, and **(3) systems of standards,** enforced by the threat of fines or jail sentences.

Market Solutions

Market negotiations concerning externality problems are based upon laws of liability. Under full liability rules, a polluter is responsible for the cost of abating pollution or compensating those affected by pollution. Under zero liability, on the other hand, the polluter has no responsibilities.

Under partial liability, compensation for pollution is required only after a specified degree of pollution has occurred. Partial liability rules may prevent either the affected or affecting parties from extorting unreasonable compensation from the liable party by claiming excessively large damages or abatement costs. **Partial liability rules can be devised to recognize the environment's ability to assimilate a certain amount of waste without significant external effects.**

Costs of making and enforcing decisions regarding pollution control, or 'transaction costs', can have a significant effect on the decision-making

process itself. For example, with the full liability rule in effect, transaction costs could result in the polluter being unable to compensate the receptors, and the polluter may decide for complete abatement. A dairy, for example, might be polluting a river and faced with the full responsibility for abating all such pollution or paying all affected citizens an amount sufficient to allow some level of pollution to continue. The firm would most likely find it very costly to seek out all affected parties and to arrive at an acceptable level of payment. It would be cheaper to quit polluting or, in this case, to cease production.

The amount of production and pollution can be influenced markedly by the type of imposed liability rule. Under a zero liability rule, the acting party which receives the payment will have more capital to work with, and may produce even more (with the subsequent ability to pollute more as well). Under a full liability rule, the acting party will have its working capital reduced because of the need to pay compensation or invest in pollution control devices. Hence, this party will produce and pollute less.

Transaction costs are likely to be larger when negotiations must be initiated by large and diffuse groups of individuals rather than by a few individuals having common interests. Thus, it follows that the full liability rule is more likely to have smaller transaction costs than the zero liability rule, and more of a chance for abatement. **The full liability rule has generally been followed in solving point source pollution problems.**

With the zero liability rule, little incentive exists for an emitter to develop or use pollution control devices. Farmers polluting through irrigation return flows generally fall in this category. Farmers may adopt pollution reduction technologies, but only if compensated for additional costs in some manner. The alternative is to shift the liability onto the farmer through threats of fines or jail sentences.

Full liability rules carry an incentive to adopt environmentally sensitive technologies. Such rules also promote the location of polluting businesses in areas where external costs to society are small. An additional argument for the full liability rule can be made on the grounds of equity. If polluters are more prosperous than affected parties, the full liability rule helps to "redistribute the wealth", and once again is more equitable than a zero liability rule.

Nonmarket Solutions

Market bargaining can solve some pollution problems, but in other cases, nonmarket policies must be implemented. Such policies include effluent standards, effluent taxes, subsidies, output taxes, input taxes, and input limits. Though generally resembling full liability policies, **these solutions are controlled by government or regulatory groups, rather than by market negotiations.** The case studies in Section 5 of the planning manual present examples of control alternatives based on effluent, output and input taxes.

Effluent Standards --

Effluent standards or emission rights are in effect a means of assigning liability limits to polluters. An effluent standard, for example, could state the amount of sediment, nitrates, or irrigation return flow allowed to leave the farm. Such standards result in the polluter being forced to abate some or all of his pollution. There may or may not be financial assistance for the polluter for meeting the costs of pollution abatement.

A policy of issuing rights to farms allowing a specific amount of pollution is conceivable, but unlikely. The amount of the emission rights issued would be determined by the environmental standard to be achieved. It would be desirable to allow trading (buying and selling) of the rights among farms within a river basin or watershed, in order to allow all farms to equate their marginal costs of abatement. Farms relying on old irrigation systems or located on soils which are difficult to control could buy rights from others in order to increase their level of emission rights.

An effluent standard is the same as a fixed resource to the farm. It can be used up to its limits, but not exceeded. The value of the standard shows the farm's value to the environment for waste disposal services, just as the price for land shows its value for crop production. Disadvantages of effluent standards are: (1) the allocation of resources may be unfair, unless trading is allowed or the initial level of allocation is based on ability to meet the standard, and (2) firms benefit from overstating their abatement costs, resulting in levels of emissions which are higher than necessary. In general, it does a relatively poor job of inducing pollution abatement technology.

The use of an emission rights (effluent standard) policy is probably not well adapted to nonpoint source pollution problems in agriculture because it requires that the level of pollution coming from the farm be identifiable and measurable. This type of policy could be useful in determining optimal abatement policies for a river basin. To meet a given environmental goal in a river basin, it might be desirable to force some farms to meet higher standards than others, while having all farms share in the associated costs.

Effluent Taxes --

Rather than issue permits or standards for pollution, it is possible to impose a tax on emissions to be paid by the polluter. Firms will react by abating pollution as long as the abatement costs are less than the tax; beyond that point they will pollute and pay the tax on emissions. Tax rates can then be adjusted to achieve the desired level of pollution abatement.

If sufficient information exists to measure the benefits of abatement, it is possible to set the effluent tax so that abatement benefits equal abatement costs. The taxes collected can be used to compensate the lost benefits of those affected by the resulting pollution. The actual economic value of abatement benefits, however is usually not easily determined. In this case, a desirable environmental quality standard is selected, then the effluent tax is adjusted to meet the standard at minimum cost. The approach presumes a full or partial liability rule to be in effect, with appropriate governmental enforcement.

For any given effluent standard, there is a tax that will result in the same degree of abatement.. That tax rate is equal to the marginal abatement cost at the given standard of pollution. Abatement is achieved by reducing production, or altering the combination of inputs.

To achieve a given level of abatement a uniform effluent standard may be more costly than a uniform effluent tax. A uniform effluent standard will cause each firm to meet the same level of emissions regardless of the firm's ability to do so. Some firms may, therefore, be forced out of business. A uniform effluent tax, on the other hand, may allow those firms unable to meet a specified standard to at least remain in operation by paying the tax and continuing to pollute. The aggregate income loss to the industry should be about the same in each case, however.

A disadvantage of the emission tax is the possibility of suboptimal investment decisions made on the basis of suboptimal tax rates. Unless the initially imposed tax is at exactly the right level, firms will incorrectly respond by making investment decisions on the basis of improper tax rates. There is the additional problem of setting up a government tax program without knowing the proper tax rate or the amount to be collected. Standards also cannot be indiscriminately changed or adjusted without imposing serious and unnecessary hardships on most industries.

Both the emission standard and the effluent tax require that a firm's effluent be readily identified and measured. This requirement is virtually impossible to meet for most nonpoint source pollution.

Subsidies --

Subsidies to reduce emissions are similar to taxes in several respects. Using subsidies, the payment is from the public to the polluting firm, rather than in the opposite direction. A level of subsidy can be devised to achieve the same level of abatement as with a tax. Firms will theoretically adjust production or use of inputs that are contributing to pollution until the level of foregone income exactly equals the level of the subsidy. This approach is obviously subject to cheating if the polluter overstates his abatement cost or accepts the subsidy and then continues to pollute. It requires careful identification of polluters and continual monitoring of their abatement programs. However, this is one approach which is commonly advocated for influencing farmers to adopt abatement control practices.

In the long run, effluent taxes and subsidies may have opposite effects on an industry. Taxes will reduce the amount of effluent from an industry as a whole. If it is known that the public will pay the costs of solving environmental problems via subsidies, an industry will grow unimpeded. Thus **although subsidies will cause a reduction in the effluent discharged per firm, they may cause an increase in the discharge from the industry as a whole.**

Output Taxes --

It is also possible to impose a tax on the product or good (for example, potatoes) whose production is causing the pollution. Again, a tax level is devised that will result in the desired level of pollution abatement. A tax on the product may be partially passed on to consumers in the form of a price increase if the entire industry faces the same output tax. Whenever the tax is imposed on only a small portion of the industry, however, that portion of the industry will probably have to adsorb the additional cost or switch to another product.

An output tax does not effectively alter the prices of inputs used in production. Thus, the combination of inputs remains unaffected. For any level of abatement, an effluent (pollutant) tax will generally be less costly than an output tax except when the output and pollutant are directly proportional to each other. This is a rare circumstance.

An output tax generally has only limited use in agriculture, since most pollution is a function of only a few inputs (such as water, fertilizer, or chemicals). Effluents would be reduced only in relation to output reductions, and input substitution would not be encouraged (e.g., increasing management or labor to reduce the amount of water and fertilizer used). A policy encouraging resource substitution would be more efficient in improving agricultural water quality; a **policy to reduce pollution of irrigation return flows, for example, would be more efficient if focused on such inputs as water and nitrogen than if guided by a tax on crop production.**

Input Taxes and Limits --

Taxing or rationing those inputs which are responsible for pollution, rather than taxing the effluent directly, is a policy better suited to agricultural pollution abatement. The need for identifying and measuring levels of emission by individual firms is eliminated. If taxing or limiting input resources could bring the price of input resources in line with their true social costs, then pollution would be reduced to the socially desirable level.

This policy alternative is practical only if the effluent results from a limited number of inputs. If there is only one input contributing to an effluent, taxing it or rationing its use can be as efficient as an effluent standard. If two inputs contribute to effluents (e.g., water and fertilizer), then taxing or limiting only one input will be less efficient than an effluent tax or standard. Only by taxing or limiting both inputs in direct proportion to their contribution to effluents will maximum efficiency be reached.

Uniform input limits or taxes applied across regions will not be equitable if regional pollution problems and production methods are not uniform. Unless a variable input limit or tax system is used, trading of input use rights should be allowed to equalize costs among regions or among farms within each region. In an irrigated river basin, for example, the responsible agency would have to estimate the total amount of water to be used within the basin and then appropriately reduce the amount of water to each farmer.

Throughout this discussion, efficiency and cost have been described only in terms of total impact on the economy. The net economic cost of any program is the sum of both its public and private costs. An effluent standard that reduces the income of farmers but imposes no other costs on the public sector would have its costs measured in terms of lost farm income only. A subsidy to farmers to affect pollution abatement would have its cost measured as the level of the subsidy, since farm income would not be decreased. These two programs could achieve similar results at simialar expenses, but with a completely different distribution of costs.

Zero Pollution

Zero pollution is not a means, but an end. **It is questionable whether zero pollution can even be met in nature, let alone under the conditions imposed by an industrial society. All human activity alters the environment in some way.** Rules insisting on zero pollution are not generally taken seriously, because most people realize that there is little room for economic activity in such cases.

The Economic Optimum

In a perfect world where all effects and all costs are measurable, the optimum would be defined by extending pollution control activities to the point where added expenditures for control are just offset by added benefits. This is a familiar rule in all of economics and it has a common sense interpretation: keep doing something as long as it pays.

In cases of nonpoint source pollution, the physical and economic data for estimating the degree of optimal control are generally not available. It is not known whether one of the hundreds of polluting farmers could solve the entire problem if he were to discontinue all activities contributing to the problem. Nor is it known whether a 10 percent reduction in all polluting activities would necessarily reduce pollution by 10 percent. The economic optimum cannot be precisely determined. Policy makers can recommend that all farmers use best management practices in order to achieve an acceptable level of pollution control, or they can set arbitrary standards and attempt to enforce these by laws, taxes, susidies, or combinations of the three.

SUMMARY

U.S. agriculture is a highly intensive industry that uses complex sets of inputs to produce huge volumes of foodstuffs. The industry has been held up as a model of efficiency in other parts of the world. Only recently have environmentalists begun to point to agriculture and indicate that some environmental problems may arise in that sector of the economy. Nonpoint source pollution from agriculture could be abated by stopping agricultural production or by reducing output to extremely small levels. It could also be abated by generating a new class of inputs that leave fewer pollutants or that are less amenable to transport into other areas or into common property resources. In any event, the structure of the industry would change in response to the change in rules about input use. The new rules would also change the output mix of agriculture, the size and distribution of income within the industry, and the relationship between agriculture and local or national economics.

SECTION 2

EVALUATING THE INCOME EFFECTS OF AGRICULTURAL NONPOINT SOURCE CONTROLS

Many results of pollution controls, for example uncertainty associated with changes in production technology or reduced recreational opportunities, are difficult to measure. **In this section, analytical methods are presented for the evaluation of those aspects of nonpoint source controls which can be quantified.** Detailed examples of some analytical techniques are provided to assist 208 planners in collecting data and developing computational methods for evaluating alternative abatement policies. The methodology described herein is only one of the many that could be useful for policy analysis. The reader interested in alternative methodologies or a more detailed description of the planning methodologies presented in this report should refer to the main report which describes case study watersheds. The original reports for these and other case studies cited may be of assistance to water quality planners.

This section focuses on the anticipated income effects of nonpoint source controls on farm operators. Generally, cost comparisons are made at the farm level, while recognizing that the final distribution of costs will be determined by the cost-sharing policies implemented. In addition, abatement choices are based on short-term maximization of profits, constant prices and do not account for the influence of non-economic objectives. In sections 4 and 5 of this report, alternative evaluation criteria are discussed.

BUDGETING PROCEDURES FOR FARM MANAGEMENT SYSTEMS

The goal of the farm manager is to allocate farm resources among production alternatives to achieve an objective. **Typically the objective used in economic analyses is the maximization of short-term profits.** Other objectives include maximization of equity, or maximization of the present value of future cash flows.

The farm manager can measure his success in maximizing short-term profits using a number of farm budgeting techniques. **Total farm budgeting or partial farm budgeting can be used to determine the profitability of existing farm enterprises and, in addition, the net income effects of any planned changes in farm activities.**

Partial Farm Budgets

When determining the profitability of adding to an existing farm enterprise or purchasing new equipment, it is not always necessary to do a total farm budget. It is often adequate to look only at the farm practices or resource requirements which will change as a result of the change in activity. This type of budgeting is commonly called partial farm budgeting.

The following information must be collected to determine relative profitability using partial budgeting methods:

1) additional receipts as a result of the change in activity,
2) reduced costs,
3) additional costs as a result of the change,
4) reduced receipts, and
5) the change in net profitability which is simply additional receipts and reduced costs less additional costs and reduced receipts.

In the case of both total and partial farm budgeting the availability of time and labor to collect records and information will limit the precision and detail of the estimates. The reader is referred to Castle et al. (1972), and Osburn and Schneeberger (1978), for a complete discussion of alternative budgeting procedures.

LINEAR PROGRAMMING APPLICATIONS

Comparing the cost of control practices for all crops on different soils and fields can be a very time-consuming and tedious process. A commonly used method for assisting in these types of computations is linear programming (LP). **Linear programming is helpful in determining and comparing the profitability of farm activities, and also in estimating aggregate farm costs for different levels of environmental controls. It is merely an efficient means of carrying out budgeting calculations described above.**

A base LP solution maximizes net farm income subject to certain restrictions on the amount of land, labor and capital available to the farm operator. The resources available to the farmer should be realistically represented by these constraints. Much of this information may have to be collected in farm visits. The information needs are exactly the same as for farm budgeting.

To estimate the cost of nonpoint source controls, constraints are normally added to limit edge-of-field losses or the amount of pollutant delivered to water courses. Since nitrogen and phosphorus as well as soil erosion occur naturally (see Section 2, Planning Manual) all losses cannot be eliminated. In addition, most conventional farming operations require fertilizer inputs and cropping rotations which will appreciably accelerate erosion and the loss of nutrients. Linear programming methods are particularly useful in establishing the relationship between loss levels and the income effects of associated pollutant control measures.

Activities included in the LP model should be chosen to reflect realistic alternatives available to farms in the area. The number of options considered, however, must be limited to prevent an unweildly amount of output.

Most cropping activities will have a certain amount of sediment loss and nitrogen and phosphorus losses associated with them. In addition, they will each generate a certain amount of income. **The linear programming solution will select the combination of activities which maximizes net farm revenues subject to constraints on the amount of these losses which can be discharged from the farm.**

In choosing resource constraints it is important to define what is meant by sediment and nutrient loss and the cost of control. Pollutant losses can be estimated at the edge of field, edge of stream, instream at point of discharge, or downstream below the point of discharge. Where specific data are available to correlate edge of stream losses to instream loading or directly to water quality parameters, this approach is preferable. **Relating instream pollutant load to corresponding instream water quality parameters, however, is very difficult; usually only edge of field and edge of stream losses can be considered in practice.**

As also discussed in Section 3 of the Planning Manual, the control cost can be defined as simple installation and maintenance costs of abatement practices, changes in farm income, the public costs of technical assistance and administration or the regional costs of changes in the agricultural product mix as a result of the nonpoint source controls. **In this section all control costs are defined as estimated changes in farm income including the costs associated with installation and maintenance of the practices.** Again, this is an incomplete assessment of total abatement costs.

NON-UNIFORM NPS TREATMENT

Brill *et al*. (1976) and Downey *et al*. (1976) have shown that using different *levels* of treatment in *different* areas can decrease pollution costs. Although they observe that uniform treatment levels within a given zone may have some advantages from both an equity and an administrative perspective, the zone designation would not have to be geographic.

Much of the methodological development of pollution control strategies has been associated with point source controls. Nonpoint source controls are not as easily included in optimization methods. This is due primarily to the lack of estimates of existing pollutant discharges and the associated cost of treatment. Although such data are generally not available, some work has been accomplished in studying the variable cost of erosion controls. Schneider and Day (1976) and White and Partenheimer (1978) have shown that the **marginal costs of adjusting to erosion controls vary appreciably between farms and between regions.** Using linear programming techniques, White and Partenheimer (1978) imposed erosion controls on twelve Pennsylvania farms. **The flexibility of the farms to change tillage and cropping practices to meet the erosion controls strongly influenced control cost.** Schneider and Day (1976) also pointed out similar differences between a number of Wisconsin farms. They also demonstrated that the marginal cost of erosion control in the eastern part of the state was much higher than marginal control costs in the western half of the state. Miller and Gill (1976) have found such differences between farms in different counties and farms of different sizes in Indiana.

SUMMARY

The evaluation of nonpoint source controls involves effectiveness and cost calculations for one set of average conditions. As these conditions change, so do cost estimates, often with a different variance. For example, practice A may control more sediment than practice B for a given field and precipitation intensity. However, a more intense rainstorm may show practice B more effective than A. It may be that the greatest pollutant losses are associated with intense rainstorms and high runoff events. Thus some preference should be given to practice A. Similarly, the variance of cost estimates will often determine the cost-effectiveness ranking of practices, particularly with those practices which have an effect on yield and crop/livestock production.

SECTION 3

EXAMPLES OF DATA COLLECTION AND ANALYSIS METHODS

This section demonstrates data compilation procedures and evaluation methods outlined in Section 2. Many of the examples are drawn from the Honeycreek Case Study presented in the planning manual.

WATERSHED DESCRIPTION

Information concerning land use, slope, soils and crop/livestock activities can be collected from secondary sources such as the U.S. Geological Survey; aerial photographs, county soils data, experiment stations, and census data. However, some of the information may have to be collected as direct field observations or in farm surveys.

Sub-watersheds

As mentioned in Section 2, it may be more cost-efficient to apply NPS controls non-uniformly in a watershed. **The criteria to sub-divide a watershed should be based on factors which are expected to change crop production costs or soil/slope/topography factors which would influence pollutant losses, the effectiveness of controls, or the extent to which farmers can adjust to controls.** For example, the Honeycreek watershed was divided into four sub-watershed areas A,B,C,D as shown in Figure F-3. Based on data collected by the U.S. Army Corps of Engineers (Honeycreek Co-occurrence Tables, 1978), the physiographic characteristics of each of the four sub-watersheds are similar, thus it was expected that control costs would differ less within sub-areas than between sub-areas. Other sub-areas could have been identified if additional data had been collected. Characteristics which might have been used to identify sub-areas include:

1) The concentrations of certain crop or livestock activities,
2) soil series,
3) drainage density, and
4) farm management systems.

Topography

Slope and slope length can be determined by a number of methods including:

1) published inventories by the Soil Conservation Service,
2) sampling by soil type or area using topographic maps, and
3) field sampling.

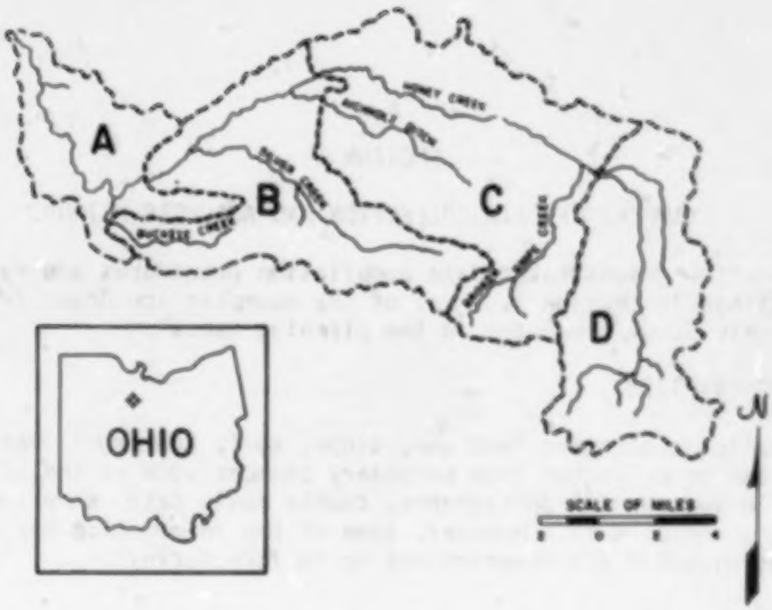


Figure F-3. Honeycreek Basin.

Each of these methods has advantages and drawbacks. Use of Soil Conservation Service (SCS) Conservation Needs Inventories (CNI) and similar surveys provides estimates of slope and slope length using a relatively small national sample (see, for example, CNI, 1978). Although there is no assurance that the soils sampled are in or near the study watershed, these estimates are based on field data which is the only accurate way of measuring slope length.

Use of topographic maps (see Appendix A) (U.S.G.S., 1979) is another method of deriving slope and slope length for the watershed in question. However, it has been demostrated that this technique greatly overestimates field-checked slope length. This is primarily due to the fact that the scale of U.S.G.S. quadrangles (1:24,000) is too small to indicate natural breaks or divisions in slope.

Field sampling is the most accurate method of determining slope and slope length. If the study watershed is nearby this can be accomplished quite easily with an abney level and tape measure. The total number of fields sampled will depend on the number of soil types or soil management groups, and the desired level of statistical confidence in the estimates. Samples of as little as 2% were used to generate CNI estimates.

Soil Type

One of the most important decisions to make in evaluating practices in a watershed is the grouping of soils for analysis. Ideally each individual soil type in the watershed should be treated separately. These soil types and their descriptions can be found in County Soil Surveys. The detail and accuracy of these surveys varies considerably between counties. For example, the Honeycreek watershed is included in four counties (Crawford, Seneca, Huron and Wyandote). Crawford and Seneca Counties have up to date soil surveys with maps (Crawford, 1975 and Seneca, 1979) while Huron and Wyandote do not (Huron, 1942). From these surveys 44 different soil types were identified. As will be demonstrated in the analyses which follow, this number of soil types is too unwiedly to work with using linear programming methods. Examples of criteria which may be used to group soils are:

1) Cropping practices and yield,
2) Soil drainage,
3) Soil erodability (k factor), and
4) Organic matter and soil nutrient levels (Appendix A lists the results of a survey indicating which states supply this information).

A practical limit to the number of soil groups which can be included in the analyses is the anticipated number of control measures which can be evaluated given time and expense limitations. Cropping rotation, tillage practices and structural control options can result in hundreds and even thousands of possible control activities. The number of man-hours in data preparation and the computational expense alone will greatly limit the number of alternatives to be considered.

Livestock Numbers/Crop Area

Often both state and federal agencies collect data on livestock numbers by county. In the case of Honeycreek, two sources of data were available:

1) U.S.D.A. census data indicating livestock numbers by county (Census, 1978), and
2) A survey conducted by Ohio State University researchers in the Honeycreek area (Venice Township, 1978).

Such information must then be used to derive livestock numbers for the watershed in question. For the Honeycreek case study, the ratio of livestock to cropland area was determined for the three principal counties in the watershed. Total livestock numbers (Table F-1) were then estimated as the county livestock density multiplied by the amount of cropland from each county in the watershed. Table F-2 indicates the breakdown of livestock by subwatershed areas.

TABLE F-1. LIVESTOCK NUMBERS FOR THE HONEYCREEK WATERSHED

County[1]	Beef Cattle[2] (#)	Milk Cows & Heifers (#)	Hogs[3] (#)	Area Cropped (HA)
Crawford (Total #)	19,100	3,300	57,448	99,190
#/HA	.193	.033	.579	
Total # in Watershed	2,672	457	8,017	
Huron (Total #)	10,700	4,600	45,236	113,360
#/HA	.044	.041	.399	
Total # in Watershed	347	149	1,466	
Seneca	15,000	4,200	50,740	134,000
#/HA	.112	.031	.379	
Total # in	2,759	773	9,334	
TOTAL/WATERSHED	5,778 (6,000)[4]	1,379 (1,500)	18,817 (20,000)	

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[1] Approximately 93% of the watershed is in Crawford, Huron and Seneca Counties.

[2] 'All cattle calves' - 'milk cows and heifers'

[3] Number of hogs marketed per year (14% breeding stock, 2 litters/year)

[4] Limits used in linear programming model.

TABLE F-2. NUMBER OF LIVESTOCK BY SUBWATERSHED, HONEYCREEK

Livestock[1]		Subwatershed A	B	C	D
	(% of Area)	(14.5)	(25.8)	(41.6)	(18.2)
Dairy Cows		217	387	623	273
Beef Cattle		870	1548	2490	1092
Hogs		2000	2400	5160	3640

[1] Number used as constraints for linear programming model

Crop areas were estimated as a function of relative prices and the extent of livestock activities. For Honeycreek approximate areas of wheat and meadow were derived from census data (17% and 6%, respectively). Most of these crops were fed to livestock. The remaining area of cropland was planted to corn and soybean during the past few years. Estimates were based on the assumption that the areas planted to relatively low valued crops such as wheat and hay do not vary greatly in the short term, whereas the areas planted to relatively high-valued row crops such as corn and soybean change yearly according to price.

Irrigation Systems

If the project area includes irrigation systems and no improvements or demonstration programs have been constructed prior to practice implementation, materials and installation costs must be obtained from other sources. Reliable cost information for larger sizes of various types of canal lining, closed conduits and water control structures can be obtained from the United States Water and Power Resources Service (formerly the Bureau of Reclamation). Fairly accurate and representative costs for smaller delivery system components, as well as various on-farm and drainage improvements, can be obtained from local irrigation equipment suppliers and manufacturers.

To extend the costs to the entire irrigated area, it is necessary to collect information for the area concerning farm sizes, field areas, lengths, and widths, field slopes, lateral lengths and the area served by each lateral, and canal and lateral capacities and cross-sections at several points in the delivery systems. To determine the types of on-farm improvements that could be implemented, it is necessary to collect information on infiltration rates, cropping patterns, depth of top soil, and localized problems such as high water tables or soil fertility levels. Some of this information can be taken from aerial photographs or detailed farm maps; much of the information, however, must be collected in the field via actual measurements and personal interviews with farmers and local irrigation company officials.

DEVELOPING CROP BUDGETS IN THE STUDY AREA

The basis of all farming enterprises is the cost and relative profitability of crop/livestock activities. As discussed in Section 2 of this appendix, each budget consists of the variable and fixed costs of producing a specific commodity. **In estimating the cost of NPS controls a partial budgeting framework is usually adopted.** Using this approach, only those budget components which are influenced by NPS controls were evaluated. The following budgets for the Honeycreek watershed provide examples of this method.

Yield Estimates

Total crop production and farm income are directly linked to crop yield, thus the estimation of existing crop yields and changes which may occur with implementation of NPS controls is very important. Sources of yield information include:

1) actual field measurements in the watershed,
2) county soil surveys,
3) research data from experiment stations, and
4) farmer estimates in watershed.

In the Honeycreek example, yield estimates were based on experiment station data.

Crop Expenses

The principal source of information for the Honeycreek budgets were estimates made by Ohio State University. Tables F-3 and F-4 outline these estimates for corn and soybeans for three different tillage systems.

Livestock Budgets

Crops can be either sold or fed to livestock. Thus a livestock budget must include the value of crops grown and fed on the farm. It also must include estimates other livestock expenses, such as housing, manure disposal and veterinary expenses. Tables F-5 to F-7 give examples of the livestock budgets used in the Honeycreek example.

ESTIMATING NPS CONTROL COSTS USING LINEAR PROGRAMMING

There are numerous ways in which linear programming can be used to estimate the costs of environmental controls. To provide an example of one approach, details of the Honeycreek LP solutions are presented.

TABLE F-3. CORN BUDGETS, HONEYCREEK WATERSHED

	Corn Conventional	Corn Minimum	Corn No-Tillage
Variable Cost			
Seed	13.33	13.33	13.33
Chemicals[1]			
Fuel, Oil, Grease[2]	11.00	10.12	9.90
Repair and Misc.[2]	23.00	21.15	20.70
Labor[2]	20.00	18.40	18.00
Sub-Total of Operating Cap.	67.33	63.00	54.93
Interest on Operating Cap.[6]	3.73	3.49	3.04
Drying[3]			
Trucking[4]			
Fertilizer[5]			
Fixed Cost			
Management costs[7]			
Machinery Deprec.	30.00	27.60	27.00
Total	101.06	94.09	84.97
Chemicals			
Atrazine	4.00	4.00	4.00
Lasso	7.50	7.50	7.50
Paraquat		2.38	2.38
Furaden			7.00

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[1] Cost added in LP

[2] Source: N. Rask and D.L. Forester, "Corn Tillage Systems - Will Energy Cost Determine the Choice," Agriculture and Energy. Academic Press, Inc., 1977. (Base Price = Conventional Till, Base price x .92 = minimum till, Base price x .90 = no-till.

[3] Drying Cost = \$.06 per bu. Cost added in LP

[4] Trucking Cost = \$.01 per bu. Cost added in LP

[5] Fertilizer function of yield cost, added in LP. Nitrogen (lbs.) = -110 + 1.876 (yield). P_2O_5 (lbs.) = 18.838 + .333 (yield) - .335 (P Test) K_2O (lbs.) = 84.844 + .25 (Yield) + 1.618 (CEC) - .33 (K Test)

[6] Interest on Operating Capital. 9.5% for 7 m. = 0.554169

[7] Management = \$.10 per bu. Cost added in LP

TABLE F-4. SOYBEAN BUDGETS, HONEYCREEK WATERSHED

	Soybean Conventional	Soybean Minimum	Soybean No-Till
Variable Costs			
Seeds	13.00	13.00	13.00
Chemicals[1]			
Fuel, Oil, Grease[2]	8.00	7.36	7.20
Repair and Misc.[2]	21.00	19.32	18.90
Labor[2]	15.00	13.80	13.50
Sub-Total Operating Cap.[3]	57.00	53.48	52.60
Interest on Operating Cap.[3]	2.71	2.54	2.50
Trucking[4]			
Fertilizer[5]			
Fixed Cost			
Management Costs[6]			
Machinery Deprec.	30.00	27.60	27.00
Total	89.71	83.08	82.10
Chemicals			
Lorox	7.50	7.50	7.50
Lasso	7.50	7.50	7.50

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[1] Chemical - cost added in LP and interest

[2] Source: N. Rask and D. L. Forester Corn Tillage Systems - Will Energy Cost Determine the Choice in Agriculture and Energy. 1977. Academic Press, Inc. (Base price = Conventional till, Base price x .92 minimum till, Base price x .90 = no-till).

[3] Interest on Operating Capital - 9.5% for 6 mo. = .0475

[4] Trucking cost = $.01 per bu. Cost added in LP

[5] Fertilizer function of yield. Cost added in LP

P_2O5 (lbs) = 26.06 + .555 (yield) - .355 (P Test)

K_2O (lbs) = 80.556 + 1.333 (yield) + .75 (CEC) - .33 (K Test)

[6] Management - 29.5 cents per bu. Cost taken out in LP

TABLE F-5. DAIRY BUDGETS, HONEYCREEK WATERSHED

	Dairy[1] Cows	Dairy[2] Replacement
Variable Costs		
Conc. Protein (SB)	41.00	138.00
Minerals	14.00	6.00
Salt and Dicol	4.00	2.00
Milk and Starter		36.00
Sub-Total Feed Cost[3]	59.00	182.00
Vet. and Med.	24.00	15.00
Breeding (DHI)	27.00	25.00
Utilities	26.00)	
Bedding	20.00)	15.00
Misc. and Supplies	20.00)	
Market Costs	72.00)	
Interest on Operating Capital	22.00	47.00
Total Variable Costs	270.00	284.00
Fixed Cost		
Labor	270.00	135.00
Interest	69.00	95.00
Cow/Calf Replacement	215.00	100.00
	554.00	330.00
Total Costs	824.00	614.00

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[1] Production 13,000 #/cow, receipts $1683/yr

[2] Replacement period birth to freshening, 36 mo.

[3] Corn/hay feed requirements accounted for separately as part of farm crop production

[4] Cow replacement = 0.35 x $614

TABLE F-6. CATTLE BUDGETS, HONEYCREEK

	Feeder[1] Steers	Cow/Calf[2]
Variable Costs		
Feeder Steer	315.00	
Purchased Supply	37.00	3.00
Vet. and Med.	4.00	7.00
Marketing	5.00	8.00
Utilities and Misc.	3.00	10.00
Sub-Total Feed Costs[3]	364.00	28.00
Interest on Operating Costs	26.00	7.00
Total Variable Costs	390.00	35.00
Fixed Costs		
Labor	16.00	27.00
Replacements		88.00
Bull		7.00
Interest on Breeding Stock		46.00
Total Fixed Costs	16.00	168.00
Total Costs	406.00	203.00

[1] 1050 lb. steer, receipts $577/steer

[2] Feeder calf and cull cow, receipts $313

[3] Corn/hay feed requirements accounted for separately

TABLE F-7. HOG BUDGETS, HONEYCREEK

	Feeder Pigs[1]	Sow/2 litters[2]
Variable Costs		
Feed Supplement	12.84	288.00
Purchased Feeders	45.00	
Marketing	2.13	22.00
Vet. and Med.	1.50	20.00
Utilities	0.75	30.00
Misc.	1.20	45.00
Interest on Feeders	1.43	
Interest on Operating Capital	0.60	19.00
Total Variable Costs	65.45	424.00
Fixed Costs		
Labor	4.50	198.00
Interest of Sows		18.00
Total Fixed Cost	4.50	216.00
Total Costs	69.95	640.00

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[1] Finish purchased feeder pigs, receipts $96/hog

[2] Farrow-finish, receipts $1440/2 litters (includes partial receipts from sale of sow, non-breeders and boars)

TABLE F-8. CROP/LIVESTOCK ACTIVITIES IN THE HONEYCREEK LP MODEL

Activity	Program Acronym	Type[1] Activity	Units
Dairy cows	DC*	L1	#
Beef feeder steers	BFS*	L1	#
Beef cow calf	BCC*	L1	#
Feeder hots	FNG*	L1	#
Sows/2 litters	S2L*	L1	#
Milk sales	SELMILK*	L2	$/cow
Steer sales	SELBFS*	L2	$/steer
Calf sales	SELBCC*	L2	$/calf
Finished hog sales	SELFNG*	L2	$/hog
Pig sales	SEL2LB*	L2	$/2 litters
Corn area	MXWCORN*	C1	ha
Soybean area	MAXWSOY*	C1	ha
Wheat area	MXWHEAT*	C1	ha
Hay area	MAXMSAD*	C1	ha
Area fall plowed	MAXFALP*	C2	ha
Area spring plowed	MAXSPRP*	C2	ha
Area chisel plowed	MAXMINP*	C2	ha
Area no-till planted	MAXNO-P*	C2	ha
Corn sales	SELCORN*	C3	$/MT
Soybean sales	SELSB*	C3	$/MT
Wheat sales	SELWHT*	C3	$/MT
Pesticide use	BUYPEST*	C2	$
Nitrogen use	BUYNITROGEN*	C2	$
Phosphorus use	BUYPHOSPHORUS*	C2	$
Corn purchase	BUYCORN*	C3	$
Soil loss(i,j)[2]	SOLOS(i,j)*	C2	MT
(i,j,k,l,m)	SijRk,Tl*	C3	ha

* - Sub watersheds A,B,C,D

[1] L1 - Monitor of livestock numbers. Return not included in objective function.

L2 - Livestock product included in objective function.

C1 - Monitor of crop production levels. Return not included in objective function.

C2 - Monitor of production method or level of control practice. Return not included in objective function.

C3 - Production activity, included in objective function.

[2] i = 1 ... 10 soil management groups

j = 1 ... 3 slope categories

k = 1 ... 4 crop rotations

l = 1 ... 4 tillage practices

TABLE F-9. LINEAR PROGRAMMING CONSTRAINTS, HONEYCREEK LP MODEL

Constraint	Program Acronym	Type[1] Constraint	Units	Constraint	Program Acronym	Type Constraint	Units
Total soil erosion	SOILLOSS	R1	MT	Price/corn	CORN*	R4	$/MT
Return/milk cow	MILK*	R4	$/cow	Price/soybean	SBEAN*	R4	$/MT
Return/steer	BEEF*	R4	$/steer	Price/wheat	WHEAT*	R4	$/MT
Return/cow-calf	BCC*	R4	$/cow	Price/hay	HAY*	R4	$/MT
Return/2 litter of hogs	BHOG*	R4	$/2 litters	Corn area	HCORN*	R2	ha
Return/finished hog	HOG*	R4	$/hog	Soybean area	HSOYB*	R2	ha
Number of dairy cows	MXDAIRY*	R2	#	Wheat area	HWHEAT*	R2	ha
Number of beef cattle	MXBEEF*	R2	#	Hay area	HMEAD*	R2	ha
Number of hogs	MXHOG*	R2	#	Area fall plowed	FALPLOW*	R2	ha
				Area spring plowed	SPRPLOW*		
Area of cropland	MAX(i,j)[2]*	R2	ha	Area chisel plowed	MINIMUM*	R2	ha
Cost of nitrogen	NIT*	R4	$/kg	Area no-tilled	NO-TILL*	R2	ha
Cost of phosphorus	PHOS*	R4	$/kg	Area contoured	CONTOUR*	R2	ha
Cost of potassium	POT*	R4	$/kg	Use of pesticides	PEST*	R3	kg
Use of nitrogen	USNIT*	R3	kg	Soil erosion by soil group	SLOSS(i,j)*	R2	MT
Use of phosphorus	USPHOS*	R3	kg	Soil erosion by subshed	SUBSHED*	R2	MT
Use of potassium	USPOT*	R3	kg				

* - Sub watersheds A,B,C,D

[1] R1 - Primary pollution control constraint - relates directly to edge-of-field, edge-of-stream or in stream loading

R2 - Primary farm resource constraint - relates directly to availability of land, labor, and capital

R3 - Secondary pollution control constraint - relates to farm use of potential pollutants

R4 - Secondary farm resource constraint - relates to economic factors such as market price

[2] i = 1 ... 10 soil management groups
j = 1 ... 3 slope categories
k = 1 ... 4 crop rotations
l = 1 ... 4 tillage practices

The evaluation of control costs in Honeycreek had three principal objectives:

1) the estimation of changes in net farm income with the imposition of control practices,

2) the demonstration of methods for evaluating combinations of practices or control strategies, and
3) the linkage of each LP solution to a pollutant pathway control.

The objective function used to estimate control costs for the Honeycreek case study maximized net farm income from all crop and livestock activities for the entire watershed.

Livestock and crop activities used in the Honeycreek LP runs are listed in Table F-8. As noted, some types of activities (L2 and C3) are associated with a direct dollar return to the farm operator in the form of livestock or crop sales. Other types of activities (L1 and C1) simply indicate total livestock or crop production levels. Of particular interest are the C2 activities which indicate the level of environmental variables for different LP solutions. These variables include soil loss, nitrogen, phosphorus and pesticide use in the Honeycreek runs.

Limits on Resource Use

Constraints acting on the objective function limit the area available for planting, livestock feed requirements, and capital available (Table F-9). Generally, these constraints should be realistic estimates of available farm resources. From a water quality viewpoint, soil loss, nutrient export and pesticide use are of interest. Constraints determine the combination of activities included in the objective function. The types and levels of activities which produce LP solutions are the basis for estimating control costs.

Constraints on resource availability used in the Honeycreek case study included typical farm resources such as land area, livestock numbers and the area devoted to particular crops (R2 constraints). **Soil erosion (R1) was the primary constraint in terms of pollutant pathway control. Use of fertilizer and pesticides as well as limitations on tillage practices (R3) were included as secondary environmental constraints.**

Parameter Estimates

Income is generated from each L2 and C3 type activity listed in Table F-8. This estimated income is derived from the crop/livestock budgets cited in Tables F-3 to F-7. Other L1, C1, and C2 activities are simply production or environmental variables of interest. The level at which these activities enter LP solutions is governed by the constraints listed in Table F-9.

For nonpoint source controls which do not influence yield, the relative changes in production costs are an accurate indicator of income penalties. Table F-10 lists differences in production costs for selected crop rotations and nonpoint source controls in the Honeycreek watershed.

TABLE F-10. CHANGES IN COST ASSOCIATED WITH SPECIFIC CROPS OR CROP ROTATIONS GIVEN THE METHODS OF PRODUCTION

	Up & Down Plowing	Contour Plowing	30.5 M Spaced[2] Diversions	61 M Spaced Diversions
Continuous Corn				
Spring plow[1]	187.25	191.59	284.78	238.18
Fall plow[1]	187.25	191.59	284.78	238.18
Minimum tillage	175.96	180.04	274.96	227.50
No-tillage	173.17	177.19	272.54	224.86
Corn/Soybean				
Spring plow	173.19	177.21	272.56	224.88
Fall plow	173.19	177.21	272.56	224.88
Minimum tillage	162.98	166.78	263.69	215.23
No-tillage	160.45	164.17	261.47	212.82
Corn/Wheat				
Spring plow	170.26	174.21	270.01	222.10
Fall plow	170.26	174.21	270.01	222.10
Minimum tillage	160.56	164.28	261.57	212.92
No-tillage	158.16	161.83	259.49	210.65
Corn/Wheat/Meadow				
Spring plow	175.17	179.23	274.28	226.75
Fall plow	175.17	179.23	274.28	226.75
Minimum tillage	165.01	168.84	265.44	217.14
No-tillage	162.79	166.57	263.51	215.04

[1] Conventional tillage

[2] Diversions amortized at 9.5% for 20 years

R1 and R2 constraints relate directly to available farm resources and pollutant losses. The area of cropland available for each soil/slope combination was reported in Table 12 of the Planning Manual. A statistical summary of the grid cell sampling procedure used to estiamte these figures is included in Appendex A.

An important element of the return figures were yield estimates. Table F-11 gives yield estimates used in the Honeycreek runs for different soils, management groups, and crop rotations. These estimates were based on county soil surveys and experiment farm data.

Estimates of soil erosion were made using the Universal Soil Loss Equation (USLE) described in Appendix A (Equation 10). For each practice evaluated pollutant loading estimates were made for combinations of soil group, slope category, crop rotation, and tillage practices. Table F-12 provides an example of these calculations for the Honeycreek watershed. Comparable tables were generated for contour farming and the two different diversion spacings (30.5 m and 61.0 m). In each case, a total of 10 soil groups were considered.

Localized Constraints

Excessive slopes, poorly drained soils and shallow soils limit certain farming and conservation practices. In Honeycreek, contouring, minimum tillage and no-tillage were not recommended for soil group 8 because these soils exhibit poor intrinsic drainage characteristics even with subsurface drainage systems. Terrace systems were not common to the watershed and generally were not recommended for poorly drained or shallow soils. They also did not appear to be acceptable to cash crop farmers in the watershed using wide equipment on the typically complex slopes found in this study area.

Parametric LP runs are simply a series of solutions with changing constraint levels. The Honeycreek solutions were generated from an unrestricted soil erosion level to increasingly stringent erosion limits. A typical run is shown in Figure F-4. Management controls used included tillage and contouring practices, vegetative practices included crop rotations, and structural controls included diversion ditches.

Point A in Figure F-4 represents the base solution where short run profits are maximized while pollutant loss is not constrained. As losses are limited from 16 to 8 Mt/ha income decreases for vegetative and structural controls, while small increases in income are realized for the management controls. The small income increase in this case is attributed to changes in tillage systems which reduce production costs and have a favorable tillage response. As soil loss is limited below 8 Mt/ha, income effects become more severe for vegetative and structural controls.

The Honeycreek model has the capability of constraining the use of nitrogen, phosphorus and pesticides as well as soil erosion. Direct control of other pollutant pathways such as overland flow and leaching were not included in the model but externally linked to the CNS model described in Appendix A.

TABLE F-11. EXAMPLES OF YIELD ESTIMATES BY SOIL GROUP, CROP ROTATION, AND TILLAGE METHOD, HONEYCREEK

Soil Group/Crop	Continuous Corn				Corn/Soybean[1]				Corn/Wheat				Corn/Wheat/Meadow			
	S[2]	F	M	NT	S	F	M	NT	S	F	M	NT	S	F	M	NT
1 Corn	6.92	6.92	6.65	6.02	3.46	3.46	3.32	3.01	3.46	3.46	3.32	3.01	2.31	2.31	2.22	2.01
Soybean					1.18	1.18	1.12	1.07								
Wheat									1.38	1.38	1.38	1.38	.92	.92	.92	.92
Hay													2.49	2.49	2.49	2.49 (7.47)[3]
2 Corn	6.15	6.15	5.7	5.65	3.08	3.08	2.85	2.83	3.08	3.08	2.85	2.83	2.03	2.05	1.90	1.88
Soybean					1.14	1.14	1.12	1.11								
Wheat									1.28	1.28	1.28	1.28	.85	.85	.85	.85
Hay													2.27	2.27	2.27	2.27 (6.81)
3 Corn	6.59	6.59	6.33	5.73	3.30	3.30	3.16	2.87	3.30	3.30	3.16	2.87	2.20	2.20	2.11	1.91
Soybean					1.28	1.28	1.21	1.16								
Wheat									1.41	1.41	1.41	1.41	.94	.94	.94	.94
Hay													2.93	2.93	2.93	2.93 (8.79)
4 Corn	5.65	5.65	5.65	5.76	2.82	2.82	2.82	2.88	2.82	2.82	2.82	2.88	1.88	1.88	1.88	1.92
Soybean					1.01	1.01	1.01	1.01								
Wheat									1.38	1.38	1.38	1.38	.92	.92	.92	.92
Hay													2.42	2.42	2.42	2.42 (7.26)
5 Corn	5.65	5.65	5.65	5.76	2.82	2.82	2.82	2.88	2.82	2.82	2.82	2.88	1.88	1.88	1.88	1.92
Soybean					1.18	1.18	1.18	1.18								
Wheat									1.45	1.45	1.45	1.45	.96	.96	.96	.96
Hay													2.49	2.49	2.49	2.49 (7.47)

(Continued)

TABLE F-11. CON'T.

Soil Group/Crop		YIELD ESTIMATE (MT/HA)															
		Continuous Corn				Corn/Soybean[1]				Corn/Wheat				Corn/Wheat/Meadow			
		S[2]	F	M	NT	S	F	M	NT	S	F	M	NT	S	F	M	NT
6	Corn	6.40	6.40	6.72	6.66	3.20	3.20	3.36	3.33	3.20	3.20	3.36	3.33	2.13	2.13	2.24	2.22
	Soybean					1.35	1.35	1.39	1.39								
	Wheat									1.45	1.45	1.45	1.45	.96	.96	.96	.96
	Hay													2.42	2.42	2.42	2.42 (7.25)
7	Corn	5.34	5.34	5.34	5.44	2.67	2.67	2.67	2.72	2.67	2.67	2.67	2.72	1.78	1.78	1.78	1.81
	Soybean					.94	.94	.94	.94								
	Wheat									1.28	1.28	1.28	1.28	.85	.85	.85	.85
	Hay													2.34	2.34	2.34	2.34 (7.03)
8	Corn	4.90	4.40	4.41	4.16	2.45	2.45	2.20	2.08	2.45	2.45	2.20	2.08	1.63	1.63	1.47	1.39
	Soybean					.91	.91	.82	.77								
	Wheat									1.04	1.04	1.04	1.04	.70	.70	.70	.70
	Hay													2.12	2.12	2.12	6.37 (2.12)
9	Corn	5.15	5.15	5.15	5.25	2.57	2.57	2.57	2.63	2.57	2.57	2.57	2.63	1.72	1.72	1.72	1.75
	Soybean					.94	.94	.94	.94								
	Wheat									1.28	1.28	1.28	1.28	.85	.85	.85	.85
	Hay													2.12	2.12	2.12	2.12 (6.37)
10	Corn	6.25	6.25	6.57	6.50	3.13	3.13	3.28	3.25	3.13	3.13	3.28	3.25	2.08	2.08	2.19	2.17
	Soybean					1.11	1.11	1.14	1.14								
	Wheat									1.35	1.35	1.35	1.35	.90	.90	.90	.90
	Hay													2.64	2.64	2.64	2.64 (7.91)

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[1] Average annual production as part of rotation

[2] S = spring plow, F = fall plow, M = minimum tillage, NT = no-tillage

[3] ( )Yield for continuous meadow

To derive estimates for diversions of 30.5 M, apply .85 factor.

To derive estimates for diversions of 61. M, apply .925 factor.

TABLE F-12. SOIL EROSION ESTIMATES FOR UP/DOWN SLOPE BY SOIL GROUP, SLOPE CATEGORY, CROP ROTATION, AND TILLAGE PRACTICE

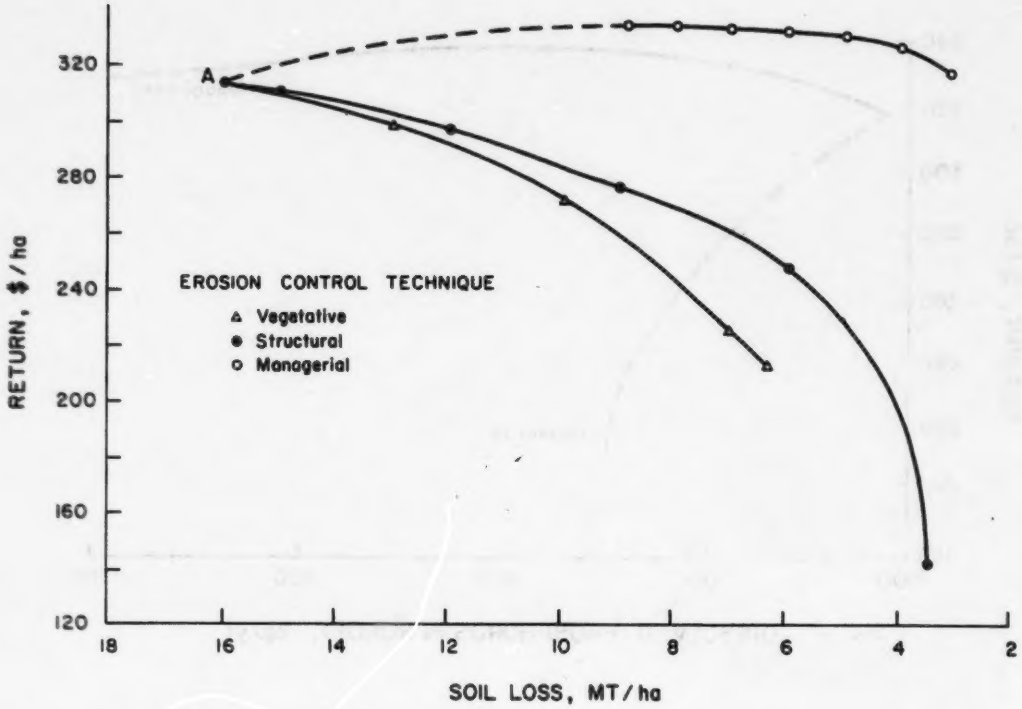
Soil Group	Slope Cat.	Continuous Corn				Corn/Soybean				Corn/Wheat				Corn/Wheat/Meadow				Continuous Meadow
		S	F	M	NT	S	F	M	NT	S	F	M	NT	S	F	M	NT	
1	1	10.06	11.12	4.98	3.45	10.58	11.66	4.98	3.45	3.79	4.51	3.52	2.76	1.37	1.59	.74	.58	.09
	2	15.09	16.68	7.46	5.16	15.89	17.48	7.46	5.16	5.96	6.75	5.29	4.12	2.06	2.38	1.12	.87	.11
	3	24.34	26.90	12.04	8.32	25.62	28.18	12.09	8.32	9.62	10.89	8.52	6.66	3.32	3.86	1.79	1.41	.18
2	1	11.75	12.98	5.81	4.01	12.35	13.58	5.81	4.01	4.64	5.25	4.10	3.21	1.61	1.86	.87	.67	.09
	2	17.60	19.46	8.72	6.03	18.54	20.38	8.72	6.03	6.95	7.87	6.16	4.82	2.40	2.78	1.30	1.01	.13
	3	38.49	42.55	19.05	13.16	40.53	44.25	19.05	13.16	14.35	16.27	12.73	4.95	4.98	5.74	2.69	2.11	.36
3	1	11.75	12.98	5.81	4.01	12.35	13.58	5.81	4.01	4.64	5.25	4.10	3.21	1.61	1.86	.87	.67	.09
	2	17.60	19.46	8.72	6.03	18.54	20.38	8.72	6.03	6.95	7.87	6.16	4.82	2.40	2.78	1.30	1.01	.13
	3	26.11	28.85	12.91	8.92	27.48	30.22	12.91	8.92	10.31	11.68	9.12	7.13	3.56	4.12	1.93	1.52	.20
4	1	13.40	14.82	6.03	4.60	14.12	15.53	6.03	4.60	5.27	6.01	4.68	3.68	1.84	2.11	.99	.78	.11
	2	20.13	22.24	9.95	6.88	21.18	23.29	9.95	6.88	7.94	9.01	7.04	5.51	2.76	3.18	1.48	1.17	.16
	3	44.27	48.93	21.90	15.13	46.58	51.27	21.90	15.13	17.46	19.79	15.49	12.10	6.05	6.99	3.25	2.56	.34
5	1	13.40	14.82	6.09	4.60	14.12	15.53	6.03	4.60	5.29	6.01	4.68	3.68	1.84	2.11	.99	.78	.11
	2	20.13	22.24	9.95	6.88	21.18	23.29	9.95	6.88	7.94	9.01	7.04	5.51	2.76	3.18	1.48	1.17	.16
	3	28.51	31.52	14.10	9.75	30.02	33.02	14.10	9.75	11.25	12.75	9.98	7.80	3.90	4.53	2.11	1.66	.22

(Continued)

TABLE F-12. CON'T.

Soil Group	Slope Cat.	Continous Corn				Corn/Soybean				Corn/Wheat				Corn/Wheat/Meadow				Continuous Meadow
		S	F	M	NT	S	F	M	NT	S	F	M	NT	S	F	M	NT	
6	1	13.40	14.82	6.09	4.60	14.12	15.53	6.03	4.60	5.29	6.01	4.68	3.68	1.84	2.11	.99	.78	.11
	2	20.13	22.24	9.95	6.88	21.18	23.29	9.95	6.88	7.94	4.01	7.04	5.51	2.76	3.18	1.48	1.17	.16
	3	31.52	34.83	15.60	10.78	33.18	36.49	15.60	10.78	12.44	14.10	11.03	8.61	4.33	4.98	2.31	1.82	.25
7	1	15.51	17.13	7.67	5.31	16.32	17.96	7.67	5.31	6.12	6.93	5.42	4.24	2.13	2.44	1.14	.90	.11
	2	23.27	25.71	11.50	7.96	24.48	26.94	11.50	7.96	9.19	10.40	8.14	6.37	3.18	3.68	1.70	1.34	.18
	3	42.34	46.78	20.96	14.48	44.54	49.02	20.90	14.48	16.77	18.94	14.82	11.57	5.78	6.68	3.12	2.44	.39
8	1	15.51	17.13	7.67	5.31	16.32	17.96	7.67	5.31	6.12	6.93	5.42	4.24	2.13	2.44	1.14	.90	.11
	2	23.27	25.71	11.50	7.46	24.48	26.94	11.50	7.96	9.19	10.40	8.14	6.37	3.18	3.68	1.70	1.34	.18
	3	32.19	35.55	15.94	11.01	34.07	37.26	15.94	11.01	12.75	14.39	11.25	8.76	4.39	5.07	2.38	1.86	.25
9	1	18.02	19.93	8.92	6.16	18.96	20.87	8.92	6.16	7.11	8.07	6.30	4.93	2.47	2.85	1.32	1.05	.13
	2	27.03	29.88	13.40	9.26	28.47	31.32	13.40	9.26	10.67	12.10	9.46	7.40	3.70	4.26	2.00	1.57	.22
	3	52.45	57.97	25.94	17.93	55.21	60.72	25.94	17.93	20.71	23.45	18.36	14.35	7.17	8.27	3.86	3.03	.43
10	1	18.02	19.93	8.92	6.16	18.96	20.87	8.92	6.16	7.11	8.07	6.30	4.93	2.47	2.85	1.32	1.05	.13
	2	27.03	29.88	13.40	9.26	28.47	31.32	13.40	9.26	10.67	12.10	9.46	7.40	3.70	4.67	2.00	1.57	.22
	3	46.04	50.88	22.77	15.76	48.46	53.33	22.77	15.76	18.18	20.60	16.12	12.60	6.30	7.26	3.38	2.67	.36

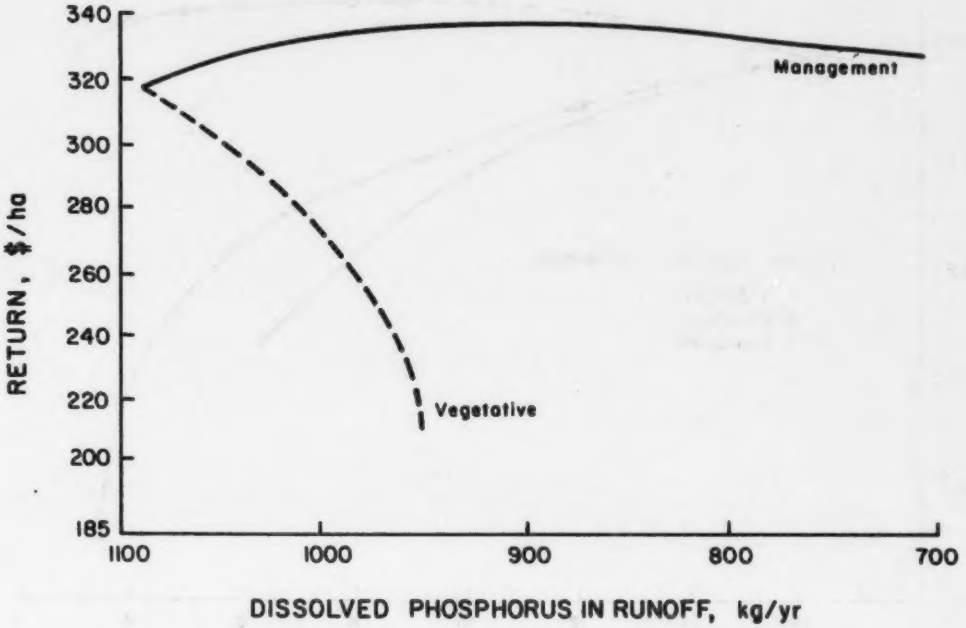
Figure F-4. Change in gross farm income for various soil loss constraints - Subwatershed A.



Nutrient Loss Estimates

Solutions to the parameteric LP runs provided input data for the CNS model to estimate solid phase and dissolved nutrient losses. Thus soil group, slope, crop, tillage practice and conservation practices were used to predict gross edge-of-field losses of nitrogen and phosphorus. Figure F-5 illustrates LP solutions for limiting dissolved phosphorus in overland flow. Again point A represents dissolved phosphorus losses in the unconstrained case. Although change in crop rotations decrease runoff potential appreciably, the cost reflected by reduced areas in row crops causes vegetative controls to be less cost effective than contouring and changes in tillage practice (management controls).

Figure F-5. Dissolved phosphorus loss in runoff from Subwatershed A for varying levels of return.



SUMMARY

Budgeting and linear programming are powerful and effective analytical tools for cost-effectiveness calculations. Pathway controls of various pollutants can be directly related to farm income effects allowing for the ranking of practices.

Because of the large array of practices which could be evaluated, methods for grouping practices are desirable. The categories used for the Honeycreek case study, management, vegetative and structural, are examples of this approach. **By focusing on control mechanisms and crop production impacts, indications of the cost-effectiveness of practices can be gained at this level of planning without the costly and tedious process of individual practice evaluation for each farm or area.**

SECTION 4

CRITERIA FOR PROGRAM DEVELOPMENT AND IMPLEMENTATION

GOALS OF FARM OPERATORS

A common assumption of economics and the basis of the linear programming calculations in the previous section is that each farmer will always be striving to maximize the net income potential from his resource base which includes land, labor, capital, and management. **The objective of income maximization may, however, be constrained by other goals, for example the desire for leisure, recreation, family vacations, education, travel, asset accumulation, or a better tractor than his neighbor's.** Family needs, windfall gains or losses, age, education, nonfarm income, equity position, risk aversion, and managerial abilities are some factors which influence financial decisions on the farm. **Normal variations in yields, crop prices, and factor costs will markedly influence the outcome of a management plan. Thus, each farmer may respond in a different manner to pollution abatement incentives.**

CLASSICAL STUDY APPROACH

Classical applications of the profit-maximizing approach to agricultural pollution control are usually constructed around single period models of "typical" or "representative" farms. The applications generally proceed in two stages. First, attention is devoted to the firm's production choices and its rate of resource use per unit of production activity. Production activities that maximize net returns to land, overhead, and management are selected subject to various combinations of inputs such as labor, fertilizer, energy, and equipment. **A profit-maximizing plan is developed without regard to resulting environmental damage.** Third party environmental spillovers, e.g., sediment and/or nutrient losses from runoff and deep percolation, are considered only in a bookkeeping sense. Estimates of gross outflows of such pollutants are made for the current profit-maximizing plan. This first stage analysis yields a baseline or benchmark solution for comparison with later (stage two) solutions in which alternative pollution abatement practices are implemented. **Differences in net farm income compared to the benchmark solution provide a measure of costs incurred to implement such practices.**

The two-stage, profit-maximizing approach offers several advantages in the study of environmental quality control. The approach is analytically tractable since the tools and data required are generally available, and the findings are readily understandable by policy makers and farm managers. In addition, the approach not only traces the impacts of alternative control measures upon farm income, but also identifies the source of such impacts.

The conventional approach may give inadequate recognition to factors that contribute to the broad spectrum of farm types and sizes observed to exist side-by-side in a given setting. All farms do not adjust to constraints similarly. **Such economic considerations as financial structure of the farm, managerial objectives and capacity, farm size, legal organization of the firm, tax treatment, and ability to bear risk may figure prominently in the ultimate direction and speed of adopting control practices.** The role of these factors in decision-making and policy analysis is difficult to capture in static profit-maximizing models. Many of the long-run goals and abilities of a farm may be overlooked when devising a plan that maximizes net income for a single production period. The potential importance of some of these factors perhaps can be illustrated by an example. Suppose a farmer is confronted with only two pollution control options: one nonstructural (e.g. different crop rotation), the other structural (e.g. new irrigation system). The static profit-maximizing model can evaluate, with little difficulty, the nonstructural variable-cost practice. It is treated much like any other variable factor of production whose effects do not extend beyond a single production period. But the durable structural practice generates a flow of services throughout its useful life. Moreover, it involves a substantial fixed cost or capital commitment. Insufficient consideration may be given to the farmer's ability to finance a large capital outlay in providing a down payment or in carrying the additional debt service. **Failure to incorporate tax considerations which are cost-reducing only for capital expenditure items might underestimate the real cost-effectiveness of the structural practice. Even if the structural practice is more cost-effective as shown by the static profit-maximizing model, financial restraints may prohibit its adoption.** A faulty policy prescription might result.

It may be that the modeling process does not adequately capture the complexity of a farmer's goal structure, including nonfinancial as well as financial considerations. Hence, the model may incorrectly measure his costs of pollution abatement. At the worst, the ranking of control practices recommended for the "representative farm" may differ from the order in which practices would actually be adopted. A less serious problem might be over- or under-estimation of the financial costs of implementing a given practice, with relative ranking of practices remaining unchanged.

A substantial body of research exists on the adjustment and adoption process of firms. In most of the firm growth literature, greater attention is given to time-dependent resource allocation problems. Firm growth research achieves this resource allocation objective by blending short-run production theory with long-run theory of investment and disinvestment. Resources held fixed in the single period setting, such as land or machinery, are allowed to vary in the long-run dynamic models. More attention can also be given to alternative goals, such as farm size, growth, and wealth accumulation.

A more dynamic analysis of control practices need not be concerned *per se* with growth strategies and the resource accumulation process, though such concerns are not totally separable from the question of abatement practice adoption. Rather, the objective may be merely to incorporate into profit-maximizing models that ability and intent to adopt control practices. Of course, every firm faces a unique set of circumstances that impact its ultimate decisions. On the surface, such uniqueness seems to leave policy oriented research in a hopeless predicament. Representative firm analyses have definite limitations, but the suggestion of a need for more dynamic analyses is not an indictment of the representative firm approach. Such analysis must be expanded, however, to encompass a "representative cross-section" of firms. **If the analysis is to be useful for policy prescriptions as well as for improved firm-level decision making, an adequate measure of response to pollution abatement incentives must be developed for groups of firms.**

ALTERNATIVE FIRM OBJECTIVES

There is a rather diverse assortment of managerial objectives throughout commercial agriculture. Such objectives differ not only in content and ranking, but also in desired level of attainment. Four managerial objectives apart from simple profit-maximization have been investigated by economists: (1) maximization of net worth, (2) maximization of the discounted present value of disposable income, (3) maximization of utility, with net worth and disposable income being rigorously quantified, and (4) maximization of utility, including intangibles related to the quality of life and/or community recognition. Simple profit-maximization models may or may not adequately capture these alternative managerial objectives. However, these alternative objectives are much more difficult to model than the single objective of short-run profit maximization, which explains the general tendency toward usage of the latter approach.

Maximization of Net Worth

Perhaps the most common of the four managerial objectives listed above is maximization of net worth. This is essentially a broadened concept of profit-maximization over time, in which the firm's equity is allowed to expand. Unlike the simple profit-maximizing approach, **the net worth objective permits accumulation both of net income and of wealth in the form of durables like land and equipment.** This explicit treatment of investment generally renders the net worth objective more appropriate than short-run profit maximization in modeling the adoption of structural pollution abatement practices.

Accumulation of investment and equity over time raises the important question of an appropriate length (horizon) for the planning process. In the context of 208 planning programs, a relatively short horizon seems most appropriate. Policy makers are rarely interested in the continuum of adjustments and growth throughout a firm's life. Instead, their concern is with immediate adjustment prospects and impacts. Likewise, farmers confronted with a decision as to control practice adoption are more interested in the immediate issues of opportunity cost and financial Accordingly, **a five to ten year planning horizon seems most appropriate. This time framework coincides with most finance periods, thereby enabling linkage of annual production decisions with longer run investment decisions. Proper consideration must be given to the time value of money, and the**

present value of net worth must be maximized through time.

Identifying Farm Management Goals

Incorporation of goal structure into an analysis of pollution control practice adoption (i.e., multi-dimensional utility analysis) is by far the most conceptually appealing approach. Both tangible and intangible goals unquestionably strike at the heart of individual firm behavior. Policy makers, however, need broad guidelines to analyze the question of control practice adoption, not firm-specific analyses for individual farmers. The infinite variation in goals and goal ranking associated with individual management decisions is completely impractical from a policy-adoption standpoint.

Of the two more tractable objectives, maximizing net worth and maximizing disposable income, maximizing net worth appears to be the best cumulative objective. The importance of disposable income must not be ignored though. Its influence on asset accumulation can be profound. It must be treated realistically within the framework of maximizing net worth.

Many behavioral differences among producers can be incorporated in a model. Differences in resource requirements, capital structure, etc. interface with the postulated objective to collectively influence adoption patterns. Operator age, for example, can play an important role even within a common objective of maximal net worth. A young operator trying to acquire initial resources most likely will exhibit a preference toward different control practices than an older operator approaching retirement and concerned with disinvestment of his holdings. Similarly, the operator's reaction to risk may differ with age. Incorporation of a suitable time horizon, and consideration of financial liquidity, can capture many of these differences.

When economic models are used to rank and choose between pollution abatement alternatives, the decision must be made whether to use an analytically simple profit-maximizing objective or more complex objectives. Certainly the answers provided by a carefully designed, single period, profit-maximizing model will be superior to those derived without a quantitative method of evaluation. Cost estimates associated with alternative abatement programs are also generally adequate for aggregate planning purposes. The recognition of the more complex managerial objectives of most farmers is instead an appeal for flexibility in adoption of pollution abatement programs.

MAJOR FARM CHARACTERISTICS

Financial Structure

Implementation of specific control practices, particularly structural ones, depends not only upon their impact on net revenues and net worth, but also on the magnitude, structure, and liquidity of a farmer's assets and liabilities. Thus, the financial structure of the farm is a critical consideration in determining the ability to adopt a particular technology. Control practices can be adopted via retained cash earnings, credit, lease, or even reduction of debt. The extent to which these sources of finance are available to a firm effectively limits the number of relevant pollution abatement practices. Cash flow becomes an overwhelming consideration. Such flow is not normally incorporated into traditional, single-period profit-maximizing approaches, but is essential to short-run net worth studies.

The long run aspects of investment decisions may significantly impact analyses of environmental technology adoption. Of specific interest is the internal and external flow of funds. The ability to secure necessary down payments for the purchase of structural control devices, the ability to meet annual obligations including household expenses and repayment of loans, the ability to purchase annual operating inputs, and the maintenance of liquidity of assets all influence a manager's decisions to adopt pollution abatement practices.

An additional financial consideration of potential importance to the 208 planning process is the length of repayment period for debt capital. **Short and long term debt capital availability may reflect different loan limits and interest rates. Nonstructural/labor intensive practices, which can be financed out of short-term operating capital loans, may also receive perferential interest rates, thus creating a bias toward such practices.** This preference might be further accentuated by greater ease in obtaining short-term credit, or thwarted by modifying the capital costs of structural investments.

Tax Structure, Legal Organization, and Farm Size

Effective tax management is an increasingly important consideration in the adoption of agricultural technologies, including pollution abatement practices. Decisions to incur large capital expenditures on abatement, in contrast with nonstructural short term methods of control, cannot be divorced from tax implications. **Significant tax savings can be realized on long-term capital outlays, such as structural control practices. Resultant after-tax profits may differ significantly from before-tax profits, thereby influencing the cost-effectiveness of alternative control measures.**

Tax Management Strategies--

Three tax management objectives which should be considered in an evaluation of the cost-effectiveness of environmental quality control options are: (1) reduction in actual out-of-pocket costs, (2) deferment of income taxes, and (3) conversion of ordinary income to capital gains. The conventional economic approach often fails to address the impact of tax management strategies on the adoption of control practices; expenses are treated in a uniform manner, simply as offsetting revenues. Little or no consideration is given to reductions in tax burden which reduce the real cost of a particular practice. Unlike control practices involving only variable costs, capital expenditures may be subject to preferential tax treatment in terms of deductible expenses, and/or special credits.

The conventional profit-maximizing approach also fails to capture the benefit from managing income flow between years; potential benefits from tax deferral and conversion of ordinary income to capital gains income are overlooked. **By deferring income tax from one tax period to another through accelerated depreciation methods, for example, short term cash availability is increased.** Thus, tax deferral can contribute to liquidity in early (and often critical) cash-flow periods. The currently available 20 percent first-year depreciation that may be applied to new or used business assets with six or more years useful life may also ease potential cash-flow difficulties and reduce the actual cost of structural practices. A maximum bonus deduction of $4,000 may be claimed in a given year for joint (husband and wife) returns, or $2,000 for single returns, corporations, or partnerships.

Investment in most depreciable property with a useful life of three or more years, which includes most structural control devices, is also eligible for an investment credit. In contrast with depreciation expense deductions, an investment credit reduces tax liability directly. In other words, a one dollar investment credit offsets one dollar of taxes. Currently, the maximum investment credit rate is 10 percent of the qualifying amount.

The following example illustrates the combined tax advantages that can be realized from a structural control practice. Suppose a farmer purchases a $70,000 center pivot irrigation system. The combined tax savings from investment credit, double-declining balance depreciation, and bonus first-year depreciation are computed in Table F-13 assuming a $10,000 salvage value, a 10-year useful life, and a 40 percent marginal tax bracket. The present value of the tax savings totals $26,020, based on a 12 percent discount rate. This figure represents over 37 percent of the $70,000 cash cost, or 43 percent of the cash cost less salvage value. Tax implications thus can be extremely important to adoption or nonadoption decisions. A farmer paying little or no taxes, on the other hand, would derive no incentives from tax considerations.

Pollution control practices that enhance the value of the farm over time, whether structural or nonstructural, further benefit from special tax treatment. Conversion of ordinary income to capital gains income realizes a greatly diminished tax liability, for the capital gains tax rate is rarely more than 40 percent of the ordinary income tax rate. This special treatment, however, is rarely considered in aggregate policy models. Planners should observe this additional tax benefit when computing farmers' costs of adopting various pollution control practices.

Farm Size--

The benefit derived from alternative tax management strategies (excluding investment credit) is dependent upon the level of farm income. One factor associated with greater income is farm size. **Resource availability, often varies directly with farm size. Given our progressive income tax structure and regressive treatment of expenses, larger farms typically benefit more from available tax advantages than do smaller farms with less income.** Consider, for example, the after-tax cost of one dollar of expense on high and low income tax brackets. The after-tax cost in a 70 percent tax bracket is only 30 cents, whereas it is 70 cents in a 30 percent bracket, and one dollar if no taxes are being paid. The impact is clear; costs of control practices may differ by farm size. Because of tax structure, more costly (before-tax) practices may in fact be more cost-effective on an after-tax basis for large farms.

Capital-intensive control practices may be more attractive to larger farms for other reasons. Large, capital-intensive farms may view labor-intensive control practices as unacceptable because of tight labor constraints or managerial difficulties.

Incorporating these size dimensions into analytical models, 208 planners will be in a better position to evaluate alternative policies. However 208 planners must also recognize that weak equity positions (large debts) may discourage additional capital investment, and that income prospects may be uncertain; both condition the extent to which tax advantages may be realized. A large debt/equity ratio may prevent additional capital expenditures for want of a down payment. Tax deduction benefits are also greater to the high equity farmer than to the low equity farmer, other things being equal. Regardless of the tax advantages, the potential after-tax income remains of fundamental concern, not the minimization of taxes!

Legal Organization--

A final consideration in assessing the role of income taxes on the adoption of environmental control practices is the legal organization of the firm. Though single proprietorship remains the dominant legal organization in commercial agriculture, incorporation is becoming increasingly more prevalent. Apart from the legal benefits, like sheltering personal assets from extensive liability, corporations also enjoy special tax treatment unavailable to single proprietorships. This differential tax treatment comes in a variety of forms; most important are different statutory tax rate limits and the ability to shelter income. Corporate tax rates are relatively constant in contrast to the progressive individual rates. Corporations face a maximum tax rate of 46 percent at present, whereas single proprietorships are taxed at a maximum rate of 70 percent. Corporations also can shelter income from taxation by retaining earnings. Each of these factors can influence the adoption of pollution abatement practices.

RISK AND UNCERTAINTY

Regardless of the type of control practices under consideration, an important factor affecting adoption is the uncertainty which producers perceive as being associated with the practice. Planners should recognize that individual producers are likely to exhibit widely varying perceptions of the risk associated with different control practices, as well as varying abilities and desires to bear perceived risks.

Four main sources of risk and uncertainty influence managerial decision-making in agriculture: (1) changes in technology, (2) changes in the legal and institutional setting, (3) yield variability, and (4) price variability. Changes in technology contribute to a farmer's uncertainty in that the ultimate impact of new technology upon the entire farm production system is unknown. Lack of familiarity with some pollution control practices may be a problem. Thus, until control practices have been widely applied in commercial agriculture, farmers can be expected to favor those practices with which they have greater familiarity or which they preceive to have little potential for adverse impact on the production system.

Institutional and legal risks are becoming increasingly important considerations to agricultural producers. Decision-makers face considerable uncertainty regarding the nature and extent of future environmental improvement requirements. The only certainty in this regard is the inevitability of more stringent environmental controls, but the degree of improvement and the method(s) implemented remain uncertain. The 208 planning process should strive to minimize risk associated with institutional instability by adoption of widespread, relatively uniform and stable standards and/or approaches to pollution abatement.

Yield variability in irrigated agriculture typically poses less risk than for dryland agriculture. The perceived risk of control practices on irrigated crop yields may be heightened, however, because of the generally higher yields from irrigated fields. This source of perceived risk is closely linked to the risk of technology changes.

Price variability perhaps poses the greatest source of risk to farmers. Its impact on the adoption of control practices may be profound; the degree of impact will depend upon crop types and the individual-grower financial situation. Cash flow problems, for example, can become severely aggravated by price fluctuations. Managers possessing limited liquid assets may tend to associate a high risk with capital intensive practices as opposed to nonstructural practices. The latter may be favored from a standpoint of reduced financial risk.

The role of risk in the adoption of pollution control practices needs to be incorporated directly into analyses of cost-effectiveness. Incorporation of risk management behavior in the evaluation of controls could strengthen the 208 planning process. Such efforts would better portray control practice cost-effectiveness.

SOCIOLOGICAL DIMENSIONS

The adoption of control practices is not exclusively an economic problem; a variety of sociolgoical factors also contribute to the ultimate behavior of decision-makers. Ethnic, educational, and communication factors are involved in the transfer and adoption of new technologies. However, incorporating sociological dimensions into economic models is difficult at best. Perhaps the best that can be hoped for is to have policy-makers, e.g., SCS and ASCS personnel, which are sensitive to some of these factors. Formal negotiations with individual farmers might be enhanced by such knowledge.

CONCLUSIONS AND IMPLICATIONS

The maximum-profit approach to evaluating cost-effectiveness of pollution control practices focusses attention on tradeoffs between pollution

TABLE F-13. COMBINED TAX SAVINGS FROM INVESTMENT CREDIT, BONUS FIRST YEAR DEPRECIATION, AND DOUBLE-DECLINING BALANCE ANNUAL DEPRECIATION ON A $70,000 CENTER-PIVOT IRRIGATION SYSTEM

Year	Marginal Tax Rate	Investment Credit[a]	Bonus First Year Depreciation[b]	Annual Depreciation[c]	Tax Savings[d]	Present Value of Tax Savings[e]
0	.40	$ 7,000	$ 4,000	$ 13,200	$ 13,880	$ 13,880.00
1	.40			10,560	4,220	3,790.40
2	.40			8,448	3,379	2,693.90
3	.40			6,758	2,703	1,924.14
4	.40			5,407	2,163	1,374.45
5	.40			4,325	1,730	981.60
6	.40			3,460	1,384	701.13
7	.40			2,768	1,107	500.79
8	.40			1,074	430	173.52
9	.40					
10	.40					
TOTAL		$ 7,000	$ 4,000	$ 56,000[f]	$ 30,996	$ 26,019.93

[a] Computed as .10 x $70,000 = $7,000.

[b] A $4,000 limit is allowed on a joint return, $2,000 on corporate returns.

[c] Based on double-declining balance applied to the adjusted basis ($70,000 - $4,000).

[d] Computed as the investment credit (first year only) plus the product of the marginal tax rate times the sum of annual and bonus (first year only) depreciation.

[e] Assumes a 12 percent discount rate; computed as tax savings x $(1+i)^{-n}$, where $i = .12$ and n = year.

[f] Assumes a $10,000 salvage value.

abatement and economic efficiency. Insufficient attention may be given to the complexity of economic incentives influencing adoption of various control practices. The static maximum-profit model does not address dynamic factors that contribute to adoption or nonadoption decisions. Such static models provide only a partial guide to the technological adjustment process. Relative efficiencies of structural and nonstructural control practices may be inaccurately assessed, and policy options may be overlooked or even misdirected.

Reformulation of the maximum-profit model to address time-dependent resource allocation problems appears fruitful in the future. Such redirection including variations in interest rates and value of the dollar, liquidity of assets, debt/equity ratios, etc., may better reflect the practice adoption process.

Managerial objectives, financial situation, tax structure, and risk and uncertainty can each impact a firm's adoption motives. Although firms will differ in response, even in comparable production settings practicality limits the extent to which such differences can be investigated. A **limited set of scenarios can be developed to characterize different groups of adoption motives. Firm size and financial situation seem most important in this regard,** for they condition the firm's treatment of risk and uncertainty, and its tax situation. Policy-makers should recognize that the age of the farmer can play an overwhelming role in adoption or nonadoption of practices, depending upon the current stage of the individual's investment/disinvestment career cycle. Preoccupation with the myriad of alternative managerial objectives seems less rewarding, however. Maximizing the discounted net worth of a firm is a promising alternative evaluation model, though it may be difficult to accurately obtain.

SECTION 5

IMPLEMENTATION INCENTIVES

Pollution abatement activities must generally be accompanied by some incentive for their adoption. It is theoretically possible to legislate standards that must be met under threat of fine or imprisonment. This procedure has been followed with respect to most industrial pollution problems. Most people agree, however, that similar incentives would be difficult to legislate and to implement with respect to the nonpoint source pollution problems of agriculture. As an alternative, it has generally been decided that "voluntary" agricultural pollution abatement will be achieved only if accompanied by sufficient subsidies to offset farmer costs.

THE FEDERAL WATER POLLUTION CONTROL ACT

The Federal Water Pollution Control Act Amendment of 1972 (PL 92-500) and the Clean Water Act of 1977 suggest that water resource development, land use planning, and environmental policies be coordinated, integrated, and updated in a continuing planning process. This process is required by each state, both for "designated" and "nondesignated" areas. Designated areas are discrete urban-industrial communities, where the principle focus of the planning process is to coordinate nonpoint and point source waste disposal controls.

Section 303 of PL 92-500 requires that each state adopt a continuing planning process that is consistent with all provisions of the Act. This process is designed to insure that the initial plan formulated under Section 208 remains effective under changing environmental conditions. Section 304 (k) (1977 Clean Water Act) further authorizes the Administrator of EPA to enter into agreements with other federal agencies to utilize their authorities and programs to support the development and implementation of state and local water quality management plans. This section recognizes that implementation of many state and local programs is dependent upon the expertise and support of other federal agencies. **Traditionally, most agricultural programs have been either production or conservation oriented, but rarely both. The extent to which past production and conservation practices will become "best management practices" is a subject of considerable current debate.**

THE PRESENT (ACP) INCENTIVE SYSTEM

The Agricultural Conservation Program is authorized in the Soil Conservation and Domestic Allotment Act approved February 29, 1936. The original Act has been amended and supplemented by the Rural Development Act of 1972 and by title 10 of the Agricultural and Consumer Protection Act of 1973. Funds for the program are authorized annually by the Congress. Originally, the ACP offered payments for land use and/or production adjustments in addition to conservation measures. Since 1944, however, its assistance has been limited to conservation measures which farmers generally would not be likely to carry out without cost-sharing aid.

The 1979 Agricultural Conservation Program, as designed by the ASCS and submitted to the Secretary of Agriculture, emphasizes enduring practices for soil and water conservation and/or environmental problem-solving on privately owned agricultural land. The national program will authorize only those practices that meet Congressionally mandated objectives. They include wind and water erosion control, water conservation, nonpoint source pollution control, forestry and wildlife enhancement, and rural clean water goals.

Initially, emphasis of the national program will be on water quality goals. A substantial national reserve will be established to fund specific project areas for water quality improvement, and for special purposes, including small farmer demonstrations. The President and Congress have generally agreed that the ACP should: (a) solve nonpoint pollution problems for agricultural lands, (b) help achieve rural clean water goals as expressed in environmental protection legislation, (c) help conserve scarce water resources, (d) control pollution from animal wastes, (e) control erosion and sedimentation on agricultural lands, and (f) help assure a continuous supply of food and fiber. Only practices that primarily contribute to these objectives will be offered for cost-sharing. In accordance with past Presidential directives, the emphasis upon using the ACP primarily for soil and water conservation and pollution abatement programs will likely be continued.

State and county committees in conjunction with development groups will determine individual practice cost-share percentage levels. **National guidelines provide that percentage levels may not exceed 80 percent of actual cost. A higher level may be approved, however, for practices in special project areas or for other practices which would not be followed without increased cost-sharing.** Cost-sharing rules change slightly over time, and are subject to some state and county modification. In general, however, they are for limited periods of time to indiviual operators. In no case are allowances to be made to offset yield or output reductions that may be associated with the application of practices. This latter constraint may substantially change farmer program choices from those suggested by economic models and/or criteria described earlier.

Two factors are obvious deterrents to the achieving of substantial improvements in water quality by means of present cost-sharing programs. The first and overriding factor is simply the low level of financial commitment to the problem. The Environmental Protection Agency has estimated capital costs as high as $10 billion to deal effectively with agricultural nonpoint source pollution. In 1977, however, the ACP was funded at a level of about $175 million. At that rate, little progress toward achieving water quality goals can be expected to occur through farmer inducements--even if all funds are directed at water quality measures. **The second factor relates closely**

to the first. To distribute the limited number of dollars in a politically tolerable manner, at state, regional, and county levels, stringent rules for cost-sharing must be used. These rules generally have the objective of spreading the dollars out, rather than inducing changes in the most critical water quality areas. The restriction of sharing only costs of pollution control practices, rather than total variable costs (including revenue reductions), and sharing costs only of conservation, not production-oriented costs hampers the adoption of control practices.

CLASSIFICATION OF PRACTICES

There are many ways that abatement control practices may be classified. For this discussion, only a distinction between temporary and permanent practices will be used. On one extreme of such a classification are practices such as changes in crop rotation, tillage practices, or fertilizer management which have no assured impact beyond a single growing season. At the other extreme are practices such as capital investments in diversion ditches, terraces, land leveling or concrete ditch lining that may be expected to last a lifetime. A host of practices fill the gap between these extremes.

As discussed earlier, **there is a bias in current programs toward the subsidization of capital investments having a long expected life.** However, case studies of pollution abatement alternatives, similar to those presented in Section 5 of the general manual, frequently show that temporary pollution abatement measures are also the most efficient, i.e. least expensive per unit of pollution abatement. Thus, we may find ourselves implementing practices inferior to those suggested by current economic evaluation procedures such as reviewed in this report.

Temporary Practices

Cropping pattern changes, filter strips, adjustments in fertilizer or water use, and use of hired management services are examples of temporary practices. Temporary measures can often abate pollution up to 50 percent of current levels with lower costs than alternative means. Their nonpermanent nature may also be an advantage in that rigidities are not built into production processes that may affect the long run ability of agriculture to adjust to new technologies or changing resource supplies. For example, adoption of a sprinkler irrigation system to abate pollution not only increases the energy intensity of that segment of agriculture, but also makes it more vulnerable to problems created by future shortages of energy supply. In an economy where funds to support pollution abatement are limited, such characteristics are not to be taken lightly.

Temporary measures are not without disadvantage, however. **Current regulations prohibit cost-sharing of any single practice on a farm more frequently than once every five years. Temporary practices are difficult to implement on a continuing basis, particularly if the allowable level of cost-sharing is based upon their net farm income effect, a feature not encompassed by current programs. Changes in crop yield, input costs, or crop practices markedly influence net income impacts of pollution abatement**

practices. The uncertainty of these factors over time make it difficult to administer programs relying upon temporary measures for abatement. Moreover, a cost-sharing program not sensitive to such factors could lead to wild fluctuations in the amount of abatement adhieved from year to year. To obtain a specified level of pollution abatement with temporary measures would require continual adjustment of program costs. In many cases, interupting the abatement process even for a single year could reduce or eliminate potential benefits achieved during periods when the practices were in effect. If temporary practices are to be employed on a continuing basis, there will have to be program incentives tailored to meet this end.

Despite some rather serious implementation problems, temporary practices should not be rejected during pollution abatement planning. Their cost per unit of pollution abatement may be so low in some cases that implementation can be achieved for little more than the cost of educating farmers about them, appealing to their civic duty regarding environmental protection. In fact, there may be limited situations in which these procedures alone would create an adequate program of continual pollution abatement.

Permanent Practices

Permanent practices of pollution abatement are generally structural in nature. Such practices, once implemented, usually have abatement effects ranging over several years. They are an investment in the future and will normally add to the total value of a farm. Examples of practices in this category range from well-designed sediment ponds, whose lifetimes may still be relatively short, to some types of terrace or irrigation systems with life expectancies of 30 years or more.

Many of the advantages and disadvantages of permanent practices were alluded to in the previous section. **The primary advantage is the relative simplicity of administration.**

INCENTIVE PROGRAMS

Voluntary adoption of pollution abatement practices in agriculture is generally assumed to require some form of subsidy. The individual goals of farmers will influence their response to incentive programs. No single incentive program can be equally attractive to all farmers. Current ACP programs are relatively rigid in defining the types of practices which can be subsidized and the manner of cost-sharing to be followed. A broader range of program incentives might be considered for the future. The use of a combination of several types of incentives is perhaps appropriate to achieve environmental standards.

Fixed Rate Cost Sharing

Cost-sharing programs have traditionally been based on the principal that a fixed rate be paid to farmers for a particular practice (e.g., a fixed number of dollars per acre for terracing, or fixed number of dollars per foot of irrigation mainline). The rates are adjusted to fit costs in different parts of the country. The approach has the advantage of being relatively easy to administer, but it has the disadvantage of not being equally attractive to all farmers in any given area. **Under a voluntary program, it elicits adoption patterns not commensurate with the problems to be solved.**

Farmers with different debt/equity ratios, ages, tax brackets, cash positions, etc. will each respond differently to such a cost-sharing program. In some cases, a farmer is paid to install an irrigation system that he would have installed even without a subsidy, whereas a neighbor may not be able to afford the investment even with a subsidy. The fixed rate program provides no assurance that it will achieve desired levels of abatement. It will not necessarily attract the right farmers or the right number of participants, and will provide either too much or too little pollution abatement for the dollars expended.

Variable Rate Cost Sharing

It is conceivable that **cost-sharing programs could be designed with more flexibility than the fixed rate approach** described above. Case studies for alternative pollution abatement practices have typically developed information for a representative farm in a given area and then measured costs of practices in terms of how they will impact net farm income. **By recognizing the relevant characteristics of individual farms, it should be possible to vary the subsidy payments for a practice to more nearly reflect the needs of each farmer.** Such flexibility would provide more assurance of obtaining the right amount of pollution abatement per dollar of program cost. Of course, the administrative costs of such a program could be prohibitively high. By focusing only on predominant differential characteristics among farmers, however, greater program flexibility could be achieved without the inordinate expense of tailoring detailed individual programs for each farm.

Tax Credit

Rather than providing direct subsidies to farmers for adopting certain practices, it is possible instead to provide tax credits against the cost of an investment. This approach is available now in a limited form to farmers who invest in new machinery or irrigation equipment. The program could be expanded to specifically attract investment to pollution abatement practices, much as homeowners are being enticed to invest in energy-saving items.

This approach has the advantage of encouraging investment of private capital in such programs, thus decreasing the need for federal expenditures. A portion of the capital invested would be offset by a reduction in the tax obligation of the farmer. This type of program would not be equally attractive to all farmers. Hence, it would not necessarily elicit investment of desirable amounts in the optimal places for pollution abatement. Low income farmers or those with large debts that already reduce their tax burdens might find little incentive through a tax credit program.

Cost of Capital

Rather than directly subsidizing farmers for investments, it is also possible to reduce the cost of capital required for such investments. This can be accomplished in several ways. Interest-free or low-interest loans provided by the action agency constitute an obvious approach. It should also be possible to guarantee loans for small or low equity farmers. Repayment periods could be adjusted to accomodate the ability of farmers to repay the incurred debt. All of these approaches have the advantage of encouraging the use of private capital to solve environmental problems.

OTHER CONSIDERATIONS

In the above discussion of program incentives, the implied costs were for long-term capital investments. There may, however, be valid reasons, including cost effectiveness, to encourage adoption of temporary practices. **It should be possible to develop a contractual arrangement between a farmer and the action agency that would ensure the long-term use for temporary practices.** Perhaps this could take the form of commitment to a series of annual payments for a given practice. It should also be possible to purchase the rights of a farmer to grow certain crops or to engage in specific practices that result in environmental damage. Such programs would have to be carefully tailored to the need of a particular area. They might provide considerably higher returns in terms of environmental improvement, however, than programs encouraging only capital investment.

Education of farmers regarding managerial adjustments that could abate pollution may provide high payoff at low cost in many cases. Frequently, a change in fertilizer management, water management, or tillage practice can provide significant environmental improvement at little or no cost to the farmer. In fact, the reduction in soil loss, fertilizer savings, or improved yields may actually increase returns to the farmer once the practice has been adopted.

There may also be situations where an environmental standard can be set for a watershed or a river basin while leaving the choice of specific abatement practices up to the farmers of the area. In most situations of this kind, some farmers will find it less costly to abate pollution than others (keeping in mind the broader definition of "costs" which was introduced in Section 1). Hence, some farmers might choose to continue polluting while giving their share of the subsidy to neighbors willing to abate a proportionately larger amount of pollution. The environmental standard could be met with greater efficiency in this manner than through a program requiring equal amounts of abatement from all farmers.

Benefits Versus Costs

It must be recognized that all environmental improvement is expected to benefit someone. It is implicity assumed, though certainly not assured, that total social benefits will equal or exceed the cost of pollution abatement. It may be possible to identify beneficiaries of environmental improvement in some areas who are willing to share the costs of improvement directly rather than through increased commodity prices in the marketplace. Under these circumstances, a mechanism would have to be arranged to accomplish the transfer of funds from one citizen's group to another.

Administrative Costs

Implementing control strategies usually requires additional accounting, monitoring, reporting, supervision, enforcement, and management. These additional costs vary substantially, according to the type of control method selected. They are usually borne both by farmers and public agencies. Administrative costs are usually not considered in deciding on a course of public action. In some cases, however, the public and private administrative costs of a program may exceed the public benefits derived from the program.

Section 208 plans require approval from a diverse set of interest groups. This approval process suggests that compromise control practices will result. The politics of local governmental bodies will, therefore, be important. Current institutional arrangements and legal frameworks may not allow some control strategies to operate, which would require the establishment of new institutional structures.

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GLOSSARY

adequacy of irrigation: The percentage of the field in which the root zone is restored to field capacity during an irrigation.

adsorption: Attraction of ions or compounds to the surface of a solid.

aerobic: Having or occurring in the presence of oxygen.

aggregate (soil): Mass or cluster of soil particles, often having a characteristic shape.

ammonification: The release of ammoniacal nitrogen from an organic nitrogen source, by biochemical processes.

ammonia volatilization: The reduction of ammonium to free nitrogen.

anaerobic: Having no oxygen, or occurring in oxygen-free conditions.

anion: Negatively charged ion; can adsorb to a soil particle.

antecedent moisture condition: Index of soil water content determined by the quantity of rainfall during a specified period preceding the time of the storm.

available nitrogen: Form of nitrogen which is immediately available for plant growth (NO_3-or NH_4+).

available nutrient: A soil molecule which can be adsorbed and assimilated by growing plants.

available phosphorus: Forms of phosphorus which can be immediately used for plant growth.

available water capacity: The difference between moisture content at -1/3 bars and at -15 bars atmospheric pressure; used as an index of moisture available to plants.

average cost: Total cost divided by total quantity of goods.

base solution: That combination of farm practices which maximizes profit when no constraints are in effect.

Best Management Practice (BMP): A practice or combination of practices found to be the most effective, practicable (including technological, economic and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

biological oxygen demand (BOD): An indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation of the organic matter at 20°C. BOD_5 refers to that oxygen demand for the initial five days of the degradation process.

biomagnification: The process by which toxic substances become concentrated in animal and plant tissues.

buffer strips: Grass or other erosion-resisting vegetation between or below cultivated fields.

bulk density: The mass of dry soil per unit bulk volume including the air space.

call period: Minimum length of time in which an irrigator is expected to place an order with the canal operator for a specified quantity of water prior to the next irrigation.

candidate measure (CM): A practice which has the potential to reduce pollutant loading, and thereby, the potential to improve water quality.

capital: The amount of property (including funds) owned by an individual or business at a specified time.

capital intensive: Requiring large amounts of capital relative to labor.

cash flow: Money which is involved in payment of debts or receipt for goods and services.

cation: Positively charged ion; can adsorb to soil particle.

center pivot sprinkler: Rotating sprinkler device; set time equals one revolution.

clay: Soil particles less than 0.002 mm in equivalent diameter.

clay soil: Soil material containing more than 40 percent clay, less than 45 percent sand and less than 40 percent silt.

cohesion: Attractive force which holds two molecules together.

common property: That which is not owned by the private sector, and is, therefore, nontransferable between individuals, e.g., air, water, etc.

conservative pollutants: Those pollutants which are not altered as they are transported from their source to the receiving water.

constraints: Limitations imposed on the farm system; usually results in different optimal combination of farm land, labor and capital when maximizing farm income.

contour farming: Plowing, planting, cultivating, harvesting and other field operations conducted on the contour.

contour ridge planting: Row crops are planted on semi-permanent ridges which follow the contour. Tillage usually occurs only on top of the ridges.

contour strip cropping: Crops which require different tillage practices are grown in alternate strips along the contours.

conventional tillage: Those primary and secondary tillage operations which are considered standard for the specific location and crop.

cost-benefit: A term used to denote the comparison of the decreases in social welfare to increases in welfare as a result of the allocation of a public good.

cost-effectiveness: A term used to compare agricultural nonpoint source control alternatives. It is generally expressed as dollars per unit pollutant load reduction.

cost-sharing: The practice whereby a public organization pays part of the cost incurred by an individual upon implementation of, for example, a pollution control measure.

cover crop: A close-growing crop whose main purpose is to protect and improve the soil during the absence of the regular crop or in the non-vegetated areas of orchards and vineyards.

crop consumptive use: The amount of water used for and transpired during plant growth plus that evaporated from the soil surface and foliage of the area occupied by the growing plant.

crop root zone: That depth of soil which is penetrated by crop roots.

crop rotation: The growing of different crops in a specified sequence on a given parcel of land.

cultural eutrophication: The process of nutrient enrichment artificially accelerated by some action(s) of human society (see "eutrophication").

curve number: An index of potential runoff developed and used by the Soil Conservation Service.

cut-back irrigation: An irrigation method wherein the head ditch is sufficiently automated so a large "wetting" furrow stream quickly advances the flow down the furrow and then the flow is reduced to a "soaking" rate to finish the irrigation.

dead level furrows: Irrigation furrows, having no slope, that are diked at the end of the furrow to prevent runoff.

deep percolation: The downward movement of water through the soil to below the crop root zone.

denitrification: The biochemical change of nitrogen from an ionic to a gaseous form.

depletable soil moisture: The quantity of moisture which can be withdrawn from the root zone without resultant crop moisture stress.

depreciation: A decrease in the value of an asset due to causes such as wear or obsolescence.

debt/equity ratio: The ratio of money borrowed to monetary value of the assets above that which is financed by another party.

desalination: The removal of salts from saline water or soil.

desorption: The release of sorbed ions or compounds from solid surfaces.

diminishing returns: Where the marginal gain decreases for each additional unit.

direct runoff: Both surface flow and the interflow component of subsurface flow.

disposable income: Income remaining after fixed costs have been subtracted.

dissolved oxygen (DO): Oxygen in lakes and streams which is readily available to the aquatic organisms.

disutility: Undesirable effects of specified action.

diversion: A channel or channels which protect a field from erosion by intercepting and diverting surface flow from croplands uphill of the given field.

drainage: Readiness with which soil water is removed from the soil profile.

drift: The unintentional transport of a substance out of the area in which it was applied.

economic risks: Monetary investments for which the benefits or returns are not guaranteed nor can the outcome be associated with a certain probability.

efficiency frontier: Locus of points indicating lowest control costs ($/kg) for a particular range of NPS load reduction.

effluent: The discharge of a pollutant, or pollutants, and the medium in which they are transported.

effluent standard: Designated limit of pollutant discharge, usually given in quantity of pollutant per unit time.

electrodialysis: Process which removes salt ions from a solution by running an electrical current through the solution; anions are attracted to the cathode and cations move toward the anode.

enrichment ratio: The ratio of pollutant concentration in the soil or soil water to its concentration in the runoff or the sediment, respectively.

EPA: Environmental Protection Agency

erosion: Detachment and movement of rocks and soil particles by water and gravity.

erosion potential index: Average annual soil loss that would occur in the absence of any vegetation or erosion-reducing practices.

eutrophication: A natural or artificial process of nutrient enrichment whereby a water body becomes abundant in aquatic plants and low in oxygen content.

evaporation pond: Basin in which wastes are retained for the purpose of reducing water and ammonia content.

evapotranspiration: The loss of water from an area by evaporation from the soil or snow cover and transpiration by plants.

evapotranspiration rate: The rate at which water is lost via plant transpiration and surface evaporation.

exchange capacity: The abundance of sites (within the soil sample) which have the potential for being actively engaged in ion adsorption.

externality: Cost associated with an activity which is not borne by the producers.

farm subsystem: That which lies within the boundary of the farm.

Federal Water Pollution Control Act (FWPCA) Amendments (PL 92-500): Legislation governing the discharge of point and nonpoint source pollutants to attain water quality goals. (Ammended in 1977, PL 95-217.)

fertility: The availability of those nutrients necessary for plant growth.

field borders: Grass strips placed at field edges where pollutants, originating from the field, can be filtered.

field capacity: The percentage of water which still remains after a recently saturated soil has drained freely for 2 or 3 days.

fixed costs: Those costs which remain constant even when the production level varies.

fragipan: Dense soil layer through which water and roots have difficulty permeating.

fungicide: Chemical used to destroy fungi.

furrow advance rate: The velocity at which the initial water stream moves down a previously dry furrow.

furrow irrigation: Irrigation method whereby water travels through the field by means of ditches between each row.

furrow length: Distance between entry point of water and end of furrow; affects efficiency of irrigation.

furrow slope: Change in elevation from head to end of furrow divided by distance, given as a percentage.

gated pipe irrigation: Irrigation method which incorporates the improved furrow and cut-back irrigation systems; length of set can be automatically controlled and varied to meet seasonal needs.

graded rows: Rows which only approximately follow the contour. This prevents row breakage by allowing excess water to leave the field.

grassed waterway: A channel covered with erosion-resisting vegetation which is used for the transport of surface water from cropland.

gravitational water: Water which moves through a soil solely by gravitational forces.

gross income: Money received for goods or services.

gross soil erosion: Soil erosion as defined by the Universal Soil Loss Equation.

groundwater: Subsurface water supply directly below the water table; zone is saturated.

groundwater runoff: Water that having infiltrated the soil surface, percolates to the groundwater table and moves laterally to reappear in surface runoff.

growing degree days: The number of consecutive days without a frost during the growing season, for a specified location.

gully erosion: Soil erosion occurring from large channels which normal tillage operations will not remove.

half-life: The time required for one half of a specified substance to disappear.

herbicides: Chemicals used to kill undesirable vegetation.

heterotrophic: Deriving energy from organic matter.

holding pond: Basin in which wastes are retained prior to disposal.

hydraulic conductivity: The readiness of a liquid to flow given a certain pressure gradient.

hydrologic condition: Description of the moisture present in a soil by amount, location, configuration, etc.

hydrologic soil group: A classification system used by the Soil Conservation Service to group soils according to drainage characteristics.

immobilization: The process by which an element becomes unavailable to other plants and organisms because of a change in form from inorganic to organic.

improved furrow irrigation: Standard furrow irrigation techniques are utilized but, by comparison to the early 1970's the scheduling of irrigation events is more closely correlated to crop needs.

infiltration: The downward entry of water into soil.

infiltration rate: A measure of the maximum rate at which water can permeate the soil under specific conditions.

inorganic: Not derived from or pertaining to an organism.

insecticides: Chemicals used to control insect population.

intake opportunity time: Quantity of time soil surface is exposed to irrigation water.

interception drainage: A type of tile drainage which collects the groundwater flows at the edge of the field and diverts them downstream, thereby removing their potential to aggregate high water table conditions.

interflow: Water that enters the soil surface and moves laterally through the upper soil layers to reappear as surface flow. Flow is above groundwater level.

irrigation delivery schedules: Plans for the timing and quantity of future irrigations based on soil moisture levels and climatic data.

irrigation efficiency (E): The fraction or percentage of water applied to an irrigated field that is stored in the crop root zone.

irrigation frequency: Number of irrigations in one season.

irrigation return flow: Surface and subsurface water which leaves the field after irrigation.

kinetic energy: Energy resulting from motion; it cannot be stored in this form.

labile: Readily coming into equilibrium.

labor intensive: That which requires a large labor input relative to capital.

land forming: Altering the characteristics of the slope and slope length.

leaching: The removal from the soil of materials which are in solution.

length of set: Amount of time irrigation water is diverted to a particular field(s).

LC_{50} Lethal Concentration: Lethal concentration of 50 percent of the species tested.

LC_{50}-Lethal Dose: Lethal dose for 50% of the organisms tested.

liability (full, partial, zero): Refers to the obligation of a producer of an externality to cover the cost of that externality.

linear programming (LP): Computational technique used to find optimal solutions for multivariable problems.

loading: Quantity of substance entering the receiving body.

macronutrient: A chemical element required, in relatively large amounts, for proper plant growth.

managerial controls: Candidate measures which involve changes in timing, chemical applicaton rates or tillage systems and usually do not involve separate field activities.

marginal cost: Cost of producing an additional unit of output. In the context of NPS control, cost of decreasing pollutant loading by an additional unit.

marginal return: Additional gain or benefit of producing an additional unit of output or decreasing pollutant loading by an additional unit.

marginal propensity to consume: That fraction of each additional dollar received that will be spent rather than saved.

market demand: That quantity of goods desired by consumers at the given price.

market supply: That quantity of goods producers are willing to supply at the given price.

meadowless rotation: A crop rotational sequence which does not include the growing of sod crops.

micronutrient: A chemical element required, in relatively small amounts, for proper plant growth.

mineralization: The microbial conversion of an element from an organic to an inorganic state.

mulch: Any substance which is spread on the soil surface to decrease the effects of raindrop impact, runoff and other adverse conditions.

multiset irrigation: Irrigation method which combines the improved furrow system with a shorter length of run; irrigations may be automatically controlled by a master control panel.

net cost: Cost of specified action after value of benefits has been deducted.

net income: Money received for goods and services after production costs have been subtracted.

net irrigation requirement: Crop consumptive use less seasonal precipitation.

nitrification: The biochemical transformation of ammoniacal nitrogen to nitrate.

nitrogen cycle: The succession of biochemical reactions that nitrogen undergoes.

nitrogen fixation: The biological process by which elemental nitrogen is converted to organic or available nitrogen.

nonpoint source (NPS): Entry of effluent into a water body in a diffuse manner so there is no definite point of entry.

no-tillage: Management practice where seeding involves only opening the soil for seed placement at the desired depth and where weed control is effected with the use of herbicides.

objective function: A mathematical statement of the program objectives, usually profit maximization or cost minimization.

opportunity costs: That which is sacrificed in taking a given course of action.

organic: Composed of carbon compounds.

osmotic pressure: The force due to water moving from an area of low concentration of a dissolved substance to that of a higher concentration of the substance.

overland flow: Water which moves across the surface of a field. Contributions to overland flow are from both direct runoff and the interflow component of subsurface flow.

pathogens: Disease-causing organisms.

percolation: The downward movement of water through soil.

permanent wilting point: (see wilting point).

permeability: The degree of penetration of gases, liquids, or plant roots through a bulk mass or layer of soil.

persistence: That period of time required for a complete degradation of a material into harmless products.

pH: Scale of acidity and alkalinity where the numbers below seven signify acidic conditions and those above, basic.

plow layer: That layer of soil disturbed by tillage.

point source: The release of an effluent from a conveyance form into a water body.

pollutant: A substance which changes our environment in an undesirable way.

pollutant delivery ratio (PDR): The fraction of a pollutant leaving an area that actually enters a water body.

porosity: Percent of soil sample not consisting of solid particles.

precipitation: Amount and intensity of rainfall that provides the transport energy for pollutant loss from cropland.

productivity: The ability of a soil to produce certain yields.

pumpback irrigation: Irrigation system in which the runoff is collected in ponds and pumped back to the top of the same or adjacent field.

pump drainage: The pumping of groundwater for the purposes of lowering the water table to alleviate waterlogging and providing additional irrigation water supplies.

rainfall erositivity: A measure of the degree to which rainfall contributes to the soil erosion process; depends on precipitation patterns and intensity.

reduced tillage: A management practice whereby the use of secondary tillage operations is significantly reduced.

relief drainage: A type of tile drainage which controls the water table elevation by intercepting and removing deep percolation from the overlying root zone.

retention ponds: Collection ponds for agricultural runoff where pollutants may settle out of solution, be assimilated by plants and organisms or degrade biochemically, depending on the nature of the pollutant.

reverse osmosis: A desalination process in which salts are forced, by an induced pressure gradient, out of the original saline solution to one of a higher concentration.

ridge planting: The practice of growing a row crop on the ridges between the furrows.

rill erosion: Soil erosion occurring from small well-defined channels which are removed during normal tillage operations.

runoff: That portion of the precipitation and/or irrigation water which appears in surface streams or water bodies.

sand: Soil whose particle size is between .05 and 2 mm in diameter.

sediment: Any eroded material which has been moved from its point of origin to be deposited on other land or in water.

sediment delivery: Sediment arriving at a specific location.

sediment delivery ratio (SDR): Fraction of eroded soil that actually reaches a water body.

sediment yield: Quantity of sediment leaving a specified land area.

seepage: Percolation losses from unlined canals, ditches, laterals, and water courses running between the point of diversion and the farm.

set time: (see length of set).

sheet erosion: Soil erosion occurring from a thin, relatively uniform layer of soil particles on the soil surface. Also called interrill erosion.

sideroll sprinkler: Mobile sprinkler device.

silt: Soil particles between .05 and .002 mm in equivalent diameter.

slope: Change in elevation over change in distance, given as a percentage.

slope length: Length of land area for which slope is measured; usually both measurements are taken along the direction of flow.

sod-based rotations: Rotational crop sequence which includes the growing of hay.

Soil and Water Conservation Practices (SWCPs): The manipulation of such variables as crops, rotation, tillage and structures to reduce the loss of soil and water.

soil erodibility: An indicator of a soil's susceptibility to raindrop impact, runoff and other erosional processes.

soil organic matter: That part of the soil originating from animal and plant material.

soil salinity: A measure of the soluble salts present in the soil.

soil solution: Water present in the soil and its solutes.

soil structure: Characteristics of the arrangements of the primary soil particles into aggregates, throughout the soil profile.

soil texture: The proportions of soil particles (sand, silt and clay) in a soil.

soil type: Lowest soil classification unit.

soil water holding capacity: Same as field capacity (inches/ft).

splash erosion: Soil erosion occurring from raindrop impact.

sprinkler irrigation: A highly efficient irrigation technique whereby water is applied to the field by spraying.

stream size: Size of irrigation water stream delivered to the head of irrigation furrows.

strip cropping: Crops which require different types of tillage are grown in alternate strips to reduce the field's potential for soil, water and pollutant losses.

structural controls: Candidate measures which require capital investment, construction activities and, consequently, certain economic risks.

subsidies: Financial aid from the government for the support of practices which are desirable to the public.

subsurface runoff: Water which infiltrates the soil and then moves laterally below the surface; includes both base flow and interflow.

tailwater: Runoff from the lower end of an irrigated field.

terrace: A relatively level raised strip of earth (usually built along the contour) used for growing crops; designed to reduce soil, water and pollutant losses.

tile drain: Subsurface pipes used to remove excess water.

tillage: Plowing and seed preparation practices.

till plant: Tillage practice where rows are scored in preparation for seeding and residues are left in and on the soil between these rows.

timing of field operations: Scheduling primary and secondary tillage practices to minimize the overall impact on the environment.

toxicity: Degree to which a chemical deleteriously affects an organism.

transaction costs (administrative costs): Cost of initiating or carrying out a specified program; involves extension, organizational and monitoring costs.

trickle irrigation: Irrigation method where the water drips from perforated tubes situated on the soil surface and running along each row.

uniformity coefficient: Indicates the relative distribution of an irrigation application; the higher the coefficient, the more uniform the application and, for the same adequacy level, the greater the irrigation efficiency.

Universal Soil Loss Equation (USLE): A method of estimating gross soil erosion by adjusting a set soil loss to the conditions present in a new situation.

utility: Degree of usefulness of a certain program or action.

variable costs: Those costs which change relative to the production level.

vegetative controls: Candidate measures which usually involve changes in the cropping system and/or land use patterns and must be renewed annually.

volatilization: Loss of a substance through evaporation.

water application requirement: Quantity of water that must be applied to the field in order to meet crop needs.

water delivery subsystem: The irrigation system component which includes the transport of the water from the headwaters of the watershed to the individual farm.

water removal subsystem: The irrigation system component which includes surface runoff from the lower end of the farm and water moving below the root zone.

watershed: The area drained by a specified stream and its tributaries.

water table: The level below which the soil or other material present is saturated.

wilting point: Soil moisture content below which plants irreversibly wilt.

zoonotic disease: Disease which is transferred from animal to man.

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